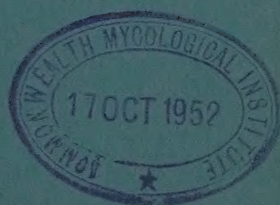# ENDEAVOUR

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The drawing on the cover is of the bark Endeavour, *which, commanded by Captain James Cook and carrying a number of scientific workers, was sent out by the British Admiralty in 1768 to chart the South Pacific Ocean and observe the transit of Venus*

ENDEAVOUR

A quarterly review designed to record the
progress of the sciences in the service
of mankind

CONTENTS

Science and the daily press

In the last half-century the part played by science in the life of nations has changed to an extent that is apt to be forgotten. Fifty years ago a man studying science in Britain had before him, as a possible career, the prospect of teaching at either a school or a university: industry took few, and the government practically none, of the young men carrying out academic scientific research. Today scientific research and administration provide a popular career. Then it was an exceptional member of the public who knew a man making a living in the laboratory or its purlieus: today he would be the exceptional who did not. Then the average home contained little that was the object of active research: today everything, from the gas-tap to the television set, speaks of applied science. Then the menace of explosives was distant and, in any case, rarely suggested science: today the aeroplane and the atomic bomb are thought of as ever-present terrors born of scientific research. To say that science dominates the daily life of our times may be an exaggeration, but it is not a great exaggeration.

The daily life should find its reflection in the daily press, but what representation does science find there, and what adequate representation is possible? There are clearly many difficulties in the way of conveying particulars of a very complex subject to readers who, while interested to the extent of a mild curiosity, are mostly untrained and uninstructed in scientific matters and are, perhaps, not willing to spend much time or to make any great effort in order to understand what is in question. It is possible to be as intrigued and excited about the structure of a variable star as about the structure of a screen star's skirt, but the one is easily explained with the aid of an illustration such as is customary in the daily press and the other is not, especially to those who will ask but who will not stay for an answer. However, looking back forty years, we see one fundamental difficulty which exists now and which did not exist then, and that is lack of space. Probably the most successful exposition of science in the daily press of recent times was Ray Lankester's series of articles which appeared in 'The Daily Telegraph' from 1907 to 1914, under the title 'Science from an Easy Chair.' These articles generally ran to two or three thousand words and were written in a leisurely manner: for instance, 'About the Stars' opened with some two hundred and fifty words concerning Hardy's novel 'Two on a Tower,' and the length of an ordinary scientific article in the British press today was exhausted before the writer really settled down to his subject. Daily papers in those days were much larger than they are now, and large numbers of readers were accustomed to devote time to reading them: evenings now spent with the broadcast programmes and with television were by many spent with a national daily. The appeal of Ray Lankester's popular scientific articles is attested by the sales of the books in which collections of them appeared: of the first of these, 'Science from an Easy Chair', eight editions appeared in five years.

Ray Lankester's success raises another question. He was, no doubt, an exceptionally gifted man with a most attractive style and a very wide range of knowledge, but, apart from occasional articles on astronomy, he devoted himself to biological subjects—jelly-fish, elephants, cholera, and clothes-moths are typical of his choice. It is generally admitted that it is easier to write for the layman on biological sciences than on the exact sciences. The living organisms concerned are often familiar, the conceptions are not so remote as those of, for instance, theoretical physics, and the teleological argument has a direct appeal. It is unlikely that there will be available a man of high distinction who can write readily and authoritatively on both of the great divisions of science, the biological and the physical. If, therefore, a balanced survey of scientific topics of general interest is to be attempted in the daily press, and if authoritative names are to be secured, it is clear that two men will be necessary. However, another difficulty is that the British daily press, while willing to pay generously for sporting paragraphs and even for astrological predictions, is, generally speaking, not accustomed to the notion of paying for scientific matter on a comparable scale. Criticism of theatre and cinema is established as a necessary feature, as is also in many papers a humorous column—and this in certain cases reaches a high level. Scientific news has attained no comparable status, and the emoluments which pertain to it are not attractive.

At present, therefore, lack of space, and lack of willingness on the part of those responsible for newspaper finance to allot funds, militate strongly against a good scientific service in the daily press. In difficult circumstances certain journalists do commendably well, obviously taking trouble to

get their facts checked whenever possible, but it is interesting to consider what should be the policy of a paper willing to put its scientific service on the same level—or something approaching the same level—as its sports service.

There is, to begin with, the question whether there should be periodical articles on general scientific subjects of current interest, as well as a scientific news service giving the latest announcement of new discovery or invention, with informed comment. In a way the former—the Ray Lankester type of article—is easier, for it can be written at leisure and, if a writer of high standing is secured, is certain to be authoritative. There are great advantages in having such articles written by a regular contributor, since he, the editor, and the public get to know one another, and the feature acquires a certain intimacy of character which helps considerably. This does not mean, of course, that there should not be two or more regular contributors: in fact, as has already been indicated, this is to be wished, since one man cannot effectively cover both great divisions of science. An occasional article by a particular authority is not of course to be excluded.

The average editor has little knowledge of the scientific world, and the choice of these regular contributors, on which so much depends, is only one of the many matters on which he will require informed and reliable advice. This fact, and the question of supplying the latest scientific news, to which we now turn, raise the problem of the type of staff required by a progressive paper. Probably an adviser outside the office is a prime necessity, a senior man of science who is active in the scientific world; but a professional journalist of scientific training, as science editor on the permanent office staff, seems to be equally desirable. One of the problems for a conscientious editor is to know whether reports that come in concern real advances, made by reputable and reliable workers, or are plausible nonsense, put forward by men or concerns who have the knack of making themselves heard and producing the impression on the layman that they have accomplished something fundamentally new and sensational. Consider the Abrams box, if an example be required. To form a quick and reliable judgment on such matters, uninfluenced by bluster, requires long experience of the doubtful suburbs, of unsavoury adventurers, and of more or less crazy enthusiasts, as well as of the reputable society of the city of science. Usually, only a man of some seniority has the knowledge and self-confidence to make a quick decision on such matters. So much for the negative side, which no-one will think unimportant who has noticed items of scientific news that occasionally appear in reputable journals. For the positive side, reports that come in by cable from unimpeachable sources are not always transcribed correctly, and here a senior adviser who can be consulted by telephone has his uses in doubtful cases. Further, for leaders on selected subjects authority is required—even if, as is general in Britain, the article is unsigned. For signed articles, a name which inspires confidence is obviously to be desired. This is a point that is well understood in the United States.

Scientific news coming in from reliable sources —and some, perhaps most, of the government scientific establishments today issue excellent reports: concise, authoritative, and clearly worded —can well be dealt with by a science editor in the office if he is the right type of man—a man scientifically trained, with wide interests and a wide arc of acquaintances in the wide scientific world, who has made scientific journalism his career. Such a man, too, is capable of writing excellent accounts of scientific stations thrown open for visit, scientific conferences, such as the annual meetings of the British Association (which are by long tradition well reported), and so on. He has here available specialists whom he can consult in case of difficulty and, when he is experienced, will readily select what can be made clear and interesting. In the ideal case, where there are two outside senior advisers, he can probably do a great deal more, but he cannot be expected to pronounce authoritatively on, say, problems of stellar astronomy, cosmic rays, atomic energy, antibiotics, and heredity.

It will be a long time, of course, before newspaper managers and editors contemplate devoting to science a tenth of the space and a tenth of the funds devoted to sport. The time may in fact never come: the comic strip and the bathing beauty may gradually extend their influence and penetrate into the more serious grounds, and such science news as appears may be presented by the strip-artist's pen and the press photograph. If, however, the problem of bringing scientific news to the daily reader is ever taken seriously, some of the points here raised will have to be considered, whatever the ultimate decision.

The seed and fruit fats of plants

T. P. HILDITCH

The fats, solid or liquid, which constitute considerable proportions of many seeds and of the external coatings of some fruits, are important raw materials. They are built up from a wide range of long-chain, mainly unsaturated, fatty acids, and their chemical constitution has many points of great interest. Especially notable is the marked tendency of related plant species to elaborate similar mixtures of specific fatty acids in their seed glycerides.

The fats or lipids which are found in the organs and storage tissues of plants and animals include a number of different types: esters of the trihydric alcohol glycerol (glycerides), esters of long-chain alcohols and steroid alcohols (ester-waxes), compounds of diacylglycerolphosphoric acids with choline or β-aminoethyl alcohol and, sometimes, carbohydrates (phospholipids) and still more complicated materials such as sphingomyelin. The fatty derivatives stored in various parts of animals and in the seeds of plants, as reserve materials, are almost wholly glycerides, that is, esters of glycerol containing three groups of long-chain fatty acids:

$$CH_2.O.CO.R'$$
$$CH.O.CO.R''$$
$$CH_2.O.CO.R'''$$
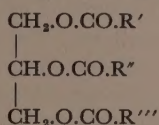
The acyl groups R', R'', R''' may be identical, but are more often different. As a general rule, the distribution of the mixture of fatty acids in a natural fat is such that any given acid seems to try to be present in as many glyceride molecules as possible. Thus, until a single acid (e.g. palmitic or oleic) forms about two-thirds or more of all the acids present in a fat, it is very unusual to find any substantial proportion of triglycerides in which only one acid is concerned (e.g. tripalmitin or triolein). The amount of glycerides containing one particular acid group is at a maximum when that acid forms one-third of the total fatty acids of a fat; the amount containing two groups of the same acid reaches a maximum if the acid in question forms two-thirds of the total fatty acids. Since, however, this even distribution of the acids among the glycerol molecules is not mathematically complete in natural products, either maximum represents only about 85–90 per cent. of the whole fat. Somewhat before a given fatty acid forms one-third of the total acids, glycerides containing two groups of such acid begin to appear, and, again, somewhat before it forms two-thirds of the total

acids in a fat, glycerides containing three groups of the acid begin to be present. For some way beyond this point, small amounts of glycerides containing only one group of the acid still persist in small and diminishing quantities.

The manner in which a fatty acid is distributed in natural glycerides is thus essentially selective in character, although it often results in a heterogeneous mixture of mixed glycerides. It is not that which would result from random assemblage of the acids into glycerides according to mathematical probability; each acid appears to compete individually for its place in the triglyceride molecules, in the manner which has been stated in the preceding paragraph. The result is most clearly evident in those fats (relatively few in number) which contain only two or three component fatty acids. Cacao butter, for instance, the acids in which consist of about 25 per cent. palmitic, 35 per cent. stearic, and 40 per cent. oleic, contains less than 1 per cent. of trisaturated glycerides, the main components being nearly 80 per cent. oleo-disaturated glycerides (55 per cent. oleopalmito-stearin and 25 per cent. oleodistearin) and about 20 per cent. of dioleo-glycerides (palmitodiolein and stearodiolein). Many fats, however, contain five, six, or even more fatty acids in comparable proportions, and, although the same general principles clearly operate in these cases, the final result is a much more heterogeneous mixture of mixed glycerides, which automatically tends more and more (as the number of component fatty acids increases) to approach that deduced from considerations of random distribution according to the rules of probability.

With few exceptions, then, the glyceride structure of a natural fat is dependent only on the proportions of its various component acids, and is independent of the particular kinds of fatty acid which may be present in it. On the other hand, the kinds and proportions of fatty acids differ widely from one natural fat to another, and much

interest attaches to the study and comparison of the different fatty acid mixtures which occur in plant and animal fats. The determination of the proportions of the different acids which make up the total fatty acids combined in any natural fat is a somewhat lengthy process, but in the past thirty years a very large number of the fatty acid mixtures present in a wide variety of plant and animal glycerides has been studied. It is not proposed to discuss here the methods which have been developed for this purpose; they have been described in detail elsewhere [1]. It may suffice to mention that the often complex mixtures of fatty acids are first resolved into simpler mixtures either, as formerly, by taking advantage of the different solubilities of their lead or lithium salts in appropriate organic solvents or, more recently, by the generally more efficient methods [2] of crystallizing the mixed fatty acids from suitable solvents (acetone or ether) at temperatures ranging from — 70° C to atmospheric. Each group of acids, in the form of methyl esters, is then distilled in a vacuum through an efficient fractionating column, and a series of ester fractions is obtained, each of which is usually sufficiently simple in character to be evaluated quantitatively. Special spectrophotometric methods [3] have been evolved for the determination of certain di- and tri-ethenoid acids, particularly the important linoleic and linolenic acids (*v. infra*) of the vegetable fats.

This tedious procedure has been recompensed by the information it has given, not only in regard to the component acids of natural fats, but notably in the revelation that their composition is closely related to the development of biological species, and to the place of the parent plant or animal in the evolutionary system [4]. Briefly, the acids in fats of the more primitive forms of aquatic life are a particularly complex mixture, characterized by the presence of considerable proportions of polyethenoid acids containing 18, 20, and 22 carbon atoms in the molecule. In the more highly developed forms of land animals and plants, the fatty acid mixture is usually very much simpler. In most animal fats, palmitic, oleic, and (often) stearic acids are the only major components. In the vegetable kingdom the mixture of acids in a fat is usually equally simple; here the chief components may be confined to a few acids such as oleic, linoleic, and palmitic; in other instances some fatty acid not found elsewhere in nature may assume major proportions.

Owing to the circumstances that a wider variety of fatty acids is encountered in fruit fats than else-where, and that this group of natural fats has so far been relatively more widely and thoroughly examined than others, it is of interest to consider in this article the mixtures of fatty acids which are specific to the fruit fats of a number of botanical families and species.
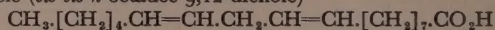
FRUIT FATS IN WHICH OLEIC, LINOLEIC, AND PALMITIC ACIDS PREDOMINATE
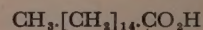
The most characteristic acids of seed or fruit fats are:

Oleic (*cis*-*n*-octadec-9-enoic)
$$CH_3.[CH_2]_7.CH{=}CH.[CH_2]_7.CO_2H$$
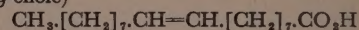
Linoleic (*cis*-*cis*-*n*-octadec-9,12-dienoic)
$$CH_3.[CH_2]_4.CH{=}CH.CH_2.CH{=}CH.[CH_2]_7.CO_2H$$

Palmitic (*n*-hexadecanoic) $CH_3.[CH_2]_{14}.CO_2H$

These three acids occur in widely varying proportions in all seed fats: no seed fat yet studied has been found to be without them, although sometimes their proportion may be small. On the other hand, many fats contain very large amounts of the two unsaturated acids, while in some fats the content of combined palmitic acid may approach one-quarter of the total fatty acids present. From a statistical survey of the fatty acids produced annually in a group of twenty vegetable fats (of which both the world production and fatty acid compositions were known with some degree of accuracy), Boekenoogen [5] concluded that, for this group, the percentage proportions of oleic, linoleic, and palmitic acids produced were respectively about 34, 29, and 11. Apart from lauric (7 per cent.), linolenic (6 per cent.), and myristic, stearic, and erucic acids (each about 3 per cent.), all the others in these twenty seed fats amounted to only about 4 per cent. of the total fatty acids therein.

It is impossible to make any near estimate for the whole range of the vegetable kingdom, but it is evident that some of the twenty examples used by Boekenoogen contain less linoleic and oleic acids than the majority of seed fats. Consequently it is probable that linoleic and oleic acids together account for something like 80 per cent. of the fats produced in fruits, with somewhat less than 10 per cent. of palmitic acid. All the other natural seed-fat acids (including more than twenty other unsaturated acids and about ten other saturated acids) probably amount to 10 per cent. or somewhat less of the total fatty acids produced by plants in their seeds.

In many plant families, linoleic and oleic acids are the preponderant components of the seed glycerides, while oleic and palmitic acids are the

most characteristic components of the fats some-times present in the external coatings of seeds.

Fruit-coat fats

In a relatively small number of fruits the external or succulent part of the fruit (mesocarp, pericarp, etc.) contains substantial proportions of fat, the most familiar being those of the olive (*Olea europaea*) and the oil palm (*Elaeis guineensis*). The composition of these fruit fats from some twenty different species has been studied in detail, and, in all cases but one, palmitic and oleic acids together form about 75–90 per cent. of the total fatty acids. The only other acid present in significant amounts is linoleic, which, however, rarely exceeds 20 per cent., and is often less than 10 per cent., of the total fatty acids. The sole exception so far observed is the wax of the myrtle berry, which is a fat consisting of glycerides of myristic (*ca.* 60 per cent.) and palmitic (*ca.* 35 per cent.) acids.

Fruit-coat fats vary in consistency from oils liquid at the ordinary temperature (such as olive oil), through pasty solids (e.g. palm oil), to hard wax-like materials which do not melt below about 50° C (*Stillingia* and sumach tallows): their melting point does not, however, depend on the presence of different kinds of fatty acid, but solely on the different proportions of palmitic and oleic (with linoleic) acids in different instances. A few examples are illustrated in table I.

The compositions of these fruit-coat fats have no apparent connection with those of the corresponding seed (kernel, endosperm) fats. Thus, while olive-kernel oil is closely similar to the ordinary pericarp oil, seed fats of the laurel family contain large amounts of the saturated lauric acid ($C_{12}H_{24}O_2$), and palm-kernel oil also contains nearly 50 per cent. of lauric acid, with significant amounts of lower and higher saturated acids.

TABLE I
Component acids of different fruit-coat fats

Species	Approximate percentage by weight		
	Palmitic	Oleic	Linoleic
Olea europaea (olive oil)	10	75–80	7–10
Laurus nobilis (laurel oil) ..	20	63	14
Elaeis guineensis (palm oil) ..	35–43	40–50	7–10
Stillingia sebifera (stillingia tallow)	66	30	—
Rhus sp. (sumach tallow) ..	75	13	—

Again, the relatively highly saturated fruit-coat tallow of *Stillingia* species encloses a seed the endosperm of which contains a very unsaturated liquid fat, in which not only linoleic and oleic acids but the triethenoid linolenic acid and a conjugated diene acid of the C_{18} series are present in some quantity.

Families whose seed fats contain mainly linoleic and oleic acids

This is an extremely large group, in which are found many familiar plants and trees. The relative proportions of the two acids vary widely in different species within the same family, and may even vary when a single species is grown under different climatic conditions, but (with only very rare exceptions) the kinds of fatty acids present in seed fats are strictly specific within a group of related plant species. Probably in the majority of seed fats in this group, linoleic acid is the major component, its amount exceeding that of oleic acid; in other cases the two acids occur in more nearly equal proportions, and, in a minority, oleic exceeds linoleic acid and becomes the major component. In all these fats there are also minor proportions (up to 10 or 12 per cent.) of palmitic acid, usually accompanied by still smaller amounts of stearic and myristic acids.

A large family of annual herbs, the *Compositae*, usually produces seed fats in which linoleic acid forms 60 per cent. or more of the total fatty acids —sunflowers, thistles, chicory, ragweed, and safflower are familiar examples. Other families are those which include the vine (*Vitaceae*); tea and camellia (*Theaceae*); poppy (*Papaveraceae*); tobacco, henbane, tomato, etc. (*Solanaceae*); sesame (*Pedaliaceae*); *Scrophulariaceae*; *Dipsaceae*; or which contain larger shrubs or trees such as the elderberry (*Caprifoliaceae*), the oak and beech (*Fagaceae*), the horse-chestnut (*Hippocastanaceae*), and the hazelnut (*Betulaceae*). In the seed fats of these larger trees, oleic more frequently predominates over linoleic acid than in those of annual herbs.

Families whose seed fats contain as a major component palmitic as well as linoleic and oleic acid

Another important group of families resembles the preceding class qualitatively, but here the proportion of palmitic acid is comparable with that of the two unsaturated acids, and in some instances reaches as much as 30 per cent. or more of the total seed fatty acids. Outstanding examples are the mallow (*Malvaceae*) and cotton and kapok (*Bombacaceae*) families, in the seed fats of which

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The articles are arranged, with regard to the subjects, in numerical order according to the Universal Decimal Classification (Brit. Std. 1000). An alphabetical key is found on page iv.

ALPHABETICAL KEY

species, of which *L. rigida* (*oiticica*) has been most studied, are similarly unique in that their seed fats contain very high proportions of keto-elaeostearic (licanic) acid; this is the only keto-acid so far observed in a natural fat.

Seed fats of the Euphorbiaceae

The spurge family is likewise distinguished by considerable variety in its seed fats. Here again some genera (*Chrozophora*, *Jatropha*, *Joannesia*) elaborate only linoleic, oleic, and a little saturated acid in their seed fats, but most members of the family include also either linolenic or some other unsaturated acid. Thus the seed fats of rubber (*Hevea*), *Stillingia*, candlenut (*Aleurites moluccana*, syn. *triloba*), and some species of *Euphorbia* include 20–30 per cent. of linolenic acid in their components, and the proportion of linolenic acid rises to 65 per cent. or more in the seed fats of *E. calycina* and of *Tetracarpidium conophorum*.

The genus *Aleurites* is remarkable in that several species other than *A. moluccana* yield seed fats in which about 80 per cent. of the combined fatty acids is the conjugated elaeostearic acid instead of linolenic acid; the seeds of *A. fordii* and *A. montana* are the source of the technically valuable tung (or China-wood) oil. Elaeostearic acid is also present in large proportions in the seed fats of *Garcia nutans* and of *Ricinodendron* species. It is believed [6] that, although linoleic and oleic acid are usually present in seed fats which contain elaeostearic acid, the latter acid and linolenic acid are not found together in the same seed fat.

Finally, in one genus (*Ricinus*) of this family a hydroxy-unsaturated acid (ricinoleic acid of castor oil) forms over 90 per cent. of the seed fat. Apart from its reported presence [7] in *Cephalocroton* (*Euphorbiaceae*), the occurrence of this acid, 12-hydroxy-oleic acid, $CH_3.[CH_2]_5.CH(OH).CH_2.CH=CH.[CH_2]_7.CO_2H$, has not yet been noticed in the seed fats of any other genus.

SEED FATS CONTAINING MONO-ETHENOID ANALOGUES OF OLEIC ACID

It will have been noticed that the polyethenoid long-chain acids of the C_{18} series so far mentioned all share one structural feature with oleic acid: unsaturation begins at the ninth carbon atom from the carboxyl group, and the molecular group

$$=CH.[CH_2]_7.CO_2H$$

is common to all. This feature, which is the more striking in view of the fact that the acids in question, with oleic, probably make up over 90 per

cent. of the unsaturated acids produced in vegetable seed fats as a whole, is very remarkable, and must surely have some relation to the chemical processes by which these acids are synthesized from carbohydrates in the living plant.

There are, however, a number of other seed fatty acids which bear structural resemblances to oleic acid in that either the group already mentioned is present, or else, as it were, the other half of the oleic acid molecule:

$$CH_3.[CH_2]_7.CH=$$

These acids (except the fifth) are:

Myristoleic (*cis-n*-tetradec-9-enoic)
$$CH_3.[CH_2]_3.CH=CH.[CH_2]_7.CO_2H$$
Palmitoleic (*cis-n*-hexadec-9-enoic)
$$CH_3.[CH_2]_5.CH=CH.[CH_2]_7.CO_2H$$
cis-n-Eicos-11-enoic $CH_3.[CH_2]_7.CH=CH.[CH_2]_9.CO_2H$
Erucic (*cis-n*-docos-13-enoic)
$$CH_3.[CH_2]_7.CH=CH.[CH_2]_{11}.CO_2H$$
Docos-13,16-dienoic
$$CH_3.[CH_2]_4.CH=CH.CH_2.CH=CH.[CH_2]_{11}.CO_2H$$
Ximenic (hexacos-17-enoic)
$$CH_3.[CH_2]_7.CH=CH.[CH_2]_{15}.CO_2H$$
Lumequic (tricos-21-enoic)
$$CH_3.[CH_2]_7.CH=CH.[CH_2]_{19}.CO_2H$$
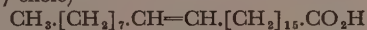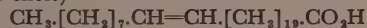
The known occurrence of the acids of greater carbon content than hexadecenoic is at present confined to two plant families and to one other unusual species in the case of the C_{20} and C_{22} acids, and to a single species in the case of the C_{26} and C_{30} acids.

Hexadec-9-enoic acid, on the other hand, is probably as widely distributed as oleic acid itself [8], but in the seed fats of land vegetation (with a single known exception) it appears only in minute proportion, probably of the order of at most 0·5 per cent. It is present in much larger amounts (usually 10–15 per cent.) in the acids of the fats of all aquatic organisms, vegetable or animal, and to a less extent in those of amphibious animals and of the lipids of land animals. In the depot fats of most land animals it forms only about 3 per cent. of the total acids, and, as already stated, in land-plant seed fats it is little more than a minute, but nevertheless definite, constituent. The solitary exception at present known is the seed fat of an Australian shrub, *Macadamia ternifolia*, belonging to the *Protaceae* [9]. This contains 20 per cent. of hexadec-9-enoic acid in addition to 60 per cent. of oleic and small amounts of saturated (chiefly palmitic) acids.

Tetradec-9-enoic or myristoleic acid is also present as a very minor component of most fats

from aquatic sources, and of land-animal fats, but, except in one instance, it has not been detected in seed fats of land vegetation. The exception here is *Pycnanthus kombo*, a member of the *Myristicaceae*; its seed fat contains nearly 30 per cent. of tetradec-9-enoic acid, the rest being mostly myristic acid [10]. In other *Myristicaceae* seed fats so far examined myristic acid is a large component (*v. infra*), but is unaccompanied by its unsaturated analogue.

Three acids in the above list are markedly characteristic of all seed fats of the *Cruciferae*, erucic acid being the best known since it forms nearly 50 per cent. of the total acids in such seed fats as mustard, rape, and other *Brassica* oils, and nearly as much in other seed fats of the families which have been examined (*Cheiranthus, Eruca, Isatis*, etc.). Eicos-11-enoic and docos-dienoic acids accompany erucic acid in much smaller amounts (5–8 per cent. of the total), while the remaining acids are mainly linoleic, with some oleic and linolenic and very small proportions of palmitic acid. The presence of small quantities of eicos-11-enoic acid in a cruciferous seed was not noticed until as recently as 1946, by Hopkins [11], in hare's-ear mustard (*Conringia orientalis*). Shortly afterwards it was detected by my colleagues [12] in ordinary rape and mustard seed oils, and it was also shown that small proportions of docos-13,16-dienoic acid invariably accompanied erucic acid in these oils. It will be seen that the diene C_{22} acid has exactly the same structural relationship to erucic acid as linoleic bears to oleic acid.

Some ten years earlier it had been observed [13] that eicos-11-enoic and erucic acids were the chief fatty acids in the lipid portion of the seeds of a shrub, *Simmondsia californica*, belonging to the family *Buxaceae*. This material is, however, unique as a seed constituent in being a wax and not a fat, for all the fatty acids are in combination not with glycerol but with a mixture of mono-ethenoid long-chain alcohols, eicos-11-enol and docos-13-enol, closely related structurally to the two acids.

Erucic acid, also, is the main constituent of the glycerides in seeds of the *Tropaeolaceae*: the fat in ordinary garden 'nasturtium' seeds contains over 80 per cent. of erucic acid and, in consequence, some 40 per cent. or more of the simple glyceride trierucin [14].

The two other acids in this group, ximenic and lumequic, have been detected so far only in the seed fat of a single species, *Ximenia americana*, of the family *Olacaceae* [15]: they belong structurally to the same group as erucic acid, i.e. with the general formula $CH_3.[CH_2]_7.CH{=}CH.[CH_2]_n.CO_2H$.

SEED FATS CONTAINING ACIDS WITH A COMMON GROUP $={}CH.[CH_2]_4.CO_2H$

An interesting group of natural unsaturated fatty acids has unsaturation beginning at the sixth atom of the carbon chain instead of at the ninth as in oleic, linoleic, and several other of the more common acids:

Petroselinic (*cis-n*-octadec-6-enoic)
$$CH_3.[CH_2]_{10}.CH{=}CH.[CH_2]_4.CO_2H$$

n-Octadec-6,9,12-trienoic
$$CH_3.[CH_2]_4.CH{=}CH.CH_2.CH{=}CH.CH_2.CH{=}CH.[CH_2]_4.CO_2H$$

Tariric (*n*-octadec-6-ynoic)
$$CH_3.[CH_2]_{10}.C{\equiv}C.[CH_2]_4.CO_2H$$

Of these, only petroselinic acid is widely distributed. It occurs in important but variable amounts in the seed fats of the large family *Umbelliferae*. It is most abundant (75 per cent. of the total acids) in parsley-seed fat, in which it was first discovered. Its presence seems to be confined almost exclusively to seed fats of this family and to those of the nearly related ivy family: elsewhere it has been reported only in one or two rare tropical species of the *Simarubaceae*. In some species of one genus (*Picramnia*) of the latter family, however, the seed fat contains large proportions of an acetylenic analogue of petroselinic acid, known as tariric acid. It is most unusual for acetylenic derivatives to be found in natural products, and in the natural fats there is so far only one other instance on record (*v. infra*).

No octadeca-6,9-dienoic acid (corresponding to linoleic acid) has yet been discovered in seed fats, but the seeds of a single species, *Oenothera biennis* (evening primrose), have been found to contain, in place of the usual linolenic acid, an analogous and isomeric triene acid with unsaturation in the 6,9,12 instead of the 9,12,15 positions in the carbon chain [16].

SEED FATS CONTAINING CYCLIC (CYCLO-PENTENYL) FATTY ACIDS

A few species of the family *Flacourtiaceae*, chiefly some of the genus *Hydnocarpus*, produce seed fats of therapeutic value in leprosy and other skin affections, an effect due to their content of cyclic unsaturated acids in which the molecule ends in a cyclopentene group:

$$\begin{array}{c} HC{=}CH \\ | \qquad \diagdown \\ H_2C{-}CH_2 \end{array}\!\!CH.[CH_2]_n.CO_2H.$$
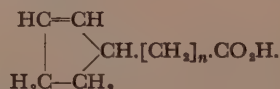
In a number of other species of this family these

cyclic acids do not appear in the seed fats, which contain only the usual mixture of linoleic with oleic and sometimes linolenic acids as major unsaturated components: all the *Flacourtiaceae* seed fats seem to contain, as so often happens, small proportions of the saturated palmitic acid.

In the seed fats of species which give rise to the cyclic acids, hydnocarpic ($C_{16}H_{28}O_2$) and chaulmoogric ($C_{18}H_{32}O_2$) acids are most abundant, and together often form about 65–80 per cent. or more of the total fatty acids; gorlic acid, $C_{18}H_{30}O_2$, with an unsaturated linking in the 6,7-position of the aliphatic chain, similar to that in petroselinic acid (*v. supra*), usually accompanies chaulmoogric acid, but is in much smaller proportions. These seed fats also contain minor amounts of oleic and palmitic acids, and traces of a group of lower even-numbered homologues of hydnocarpic acid, down to the simple *cyclo*-pent-2-enyl carboxylic acid $C_5H_7.CO_2H$ [17].

The structures of the chief acids of the group are:

Hydnocarpic $C_{16}H_{28}O_2$ 11-*cyclo*-pent-2-enyl-*n*-undecanoic

Chaulmoogric $C_{18}H_{32}O_2$ 13-*cyclo*-pent-2-enyl-*n*-tridecanoic

Gorlic $C_{18}H_{30}O_2$ 13-*cyclo*-pent-2-enyl-*n*-tridec-6-enoic

SOME ABNORMAL UNSATURATED ACIDS OF SEED FATS

There remain a few instances in which quite unusual unsaturated acids have been observed in one or another seed fat, usually from tropical sources, and of course it is very likely that others still remain undiscovered.

Known acids of this category include those of the C_{10}, C_{12}, and C_{14} series found [18] in a few species of *Lindera* and *Litsea* (*Lauraceae*), with the general formula of dec- (dodec-, tetradec-)-4-enoic acids $CH_3.[CH_2]_n.CH=CH.[CH_2]_2.CO_2H$. Oils from the seeds of *Sapium* species (*Euphorbiaceae*) are so far unique in containing, in addition to the usual linoleic, linolenic, and oleic group, about 5 per cent. of the conjugated deca-2,4-dienoic acid, $CH_3.[CH_2]_4.CH=CH.CH=CH.CO_2H$, with the conjugated system adjacent to the carboxyl group [19].

Another remarkable acid, this time belonging to the C_{18} series, is that present in the seeds of *Onguekoa gore* Engler (*Olacaceae*). It contains a terminal vinyl group and two acetylenic groups, with unsaturation starting at the C_9 position (the only conventional feature about this anomalous acid); its structure is uncertain, but may be $CH_2=CH.[CH_2]_4.C\equiv C.C\equiv C.[CH_2]_7.CO_2H$ [20].

SEED FATS CONTAINING MAJOR PROPORTIONS OF SATURATED FATTY ACIDS

We have seen that palmitic acid, $CH_3.[CH_2]_{14}.CO_2H$, is an invariable component of seed fats. Other members of the normal saturated aliphatic series, with an even number of carbon atoms in the molecule, are specific to various plant families; they include *n*-octanoic, *n*-decanoic (capric), lauric ($C_{12}H_{24}O_2$), myristic ($C_{14}H_{28}O_2$), stearic ($C_{18}H_{36}O_2$), arachidic ($C_{20}H_{40}O_2$), behenic ($C_{22}H_{44}O_2$), and lignoceric ($C_{24}H_{48}O_2$) acids. There is a fundamental difference between the occurrence of such saturated acids and that of the unsaturated acids which we have been discussing so far. Whereas the unsaturated members are almost always confined to acids of one and the same carbon content, any one saturated acid present in major proportions is invariably accompanied by subordinate proportions of the acids with two carbon atoms less, and with two carbon atoms more, than the major saturated component. Thus when, as in seed fats of the mallow and cotton families, palmitic acid becomes a major component, subsidiary amounts of myristic and stearic acids always appear. Even when, as often happens, palmitic acid forms only 10 per cent. or less of the total acids in a seed fat (the rest being unsaturated acids) it is usually accompanied by a small amount of stearic, and often also of myristic, acid.

Stearic acid is comparatively rare as a major component of seed fats, occurring only in those of a few tropical families (notably *Guttiferae*, *Dipterocarpaceae*, *Sterculiaceae*, and *Sapotaceae*). Cacao (*Theobroma cacao*) butter is the most familiar instance, its acids including 35 per cent. of stearic and 24 per cent. of palmitic; in some other seed fats, e.g. of *Allanblackia* and *Garcinia* species (*Guttiferae*), stearic acid forms over 50 per cent. of the total acids, accompanied by 3–5 per cent. of palmitic acid and traces of arachidic acid. The proportion of stearic acid varies widely in seed fats of these plant families, but rarely falls below 20–25 per cent. of the total acids.

The three naturally occurring saturated acids (arachidic, behenic, and lignoceric) of higher carbon content than stearic are almost always present as a mixture in leguminous seed fats, but their total amount is often not large (6–15 per cent. of the total acids). The presence of this mixture of acids is nevertheless quite characteristic of leguminous seeds. In some instances, one or other acid attains more important proportions, e.g. 25 per cent. of lignoceric acid in *Adenanthera* seed fat. Arachidic acid is also the major saturated acid

component of seed fats of the family *Sapindaceae*, in which it may form from 20 to over 30 per cent. of the total acids. In other fats, such as those from *Pentaclethra* species (*Leguminosae*) or *Lophira* species (*Ochnaceae*), behenic acid forms 15–20 per cent. of the total acids. The occurrence of any of these acids in large proportions is sporadic and infrequent, and is confined to seeds of the plant families mentioned.

The distribution of saturated acids of carbon content lower than that of palmitic acid is also extremely specific. Myristic acid is the preponderating constituent of all *Myristicaceae* fats so far examined, including that of the nutmeg, in which it represents over 70 per cent. of the total acids. Myristic and lauric acids contribute more or less equally in making up about 75–85 per cent. of the seed fatty acids of members of some other families, notably *Salvadora* (*Salvadoraceae*), *Erisma* (*Vochysiaceae*), and *Irvingia* (*Simarubaceae*).

Lauric acid is the characteristic acid of *Lauraceae* seed fats, in many species of which (*Litsea, Cinnamomum, Actinodaphne*) it forms 90 per cent. or so of the total fatty acids, being accompanied by very minor proportions of decanoic and myristic acids. In seed fats of the *Palmae* there is found an unusually close agreement in the quantitative distribution of fatty acids over the whole of this widely distributed family with its many diverse kinds of fruit: the total fatty acids invariably contain 45–50 per cent. of lauric and 15–20 per cent. of myristic acid as major components, accompanied by about 3–7 per cent. each of decanoic and octanoic on the one hand, and of palmitic and stearic on the other. In both constancy and complexity of the mixture of fatty acids present, the seed fats of the palm family form the outstanding instance of specificity of fatty acid composition within a single botanical family.

The elm (*Ulmaceae*) is quite unusual in that its seeds contain large proportions of decanoic (capric) glycerides.

BIOSYNTHESIS OF SEED FATTY ACIDS FROM CARBOHYDRATE PRECURSORS

It has been known for many years that fats are produced in vegetable seeds from carbohydrate materials (probably hexoses), but experimental evidence as to the manner in which the synthesis is effected is still completely lacking. Light might be thrown on the problem by studies of the development of fat in some of the larger seeds; such studies should be practicable and might well be undertaken with advantage. As it is, only conjectural explanations of the possible synthetic mechanisms can be offered at present.

While the glycerol in fats is clearly derivable from triosephosphoric acids producible from hexoses during enzyme attack, the origin of the fatty acids (which are probably first synthesized as such and then combined with glycerol) has been variously suggested to depend on the conversion of hexose to C_2 (acetaldehyde-like) or C_3 (pyruvic acid) units, or even to be the result of direct linking of hexose (or pentose) units: in any of these cases, of course, replacement of the sugar hydroxyl groups by hydrogen, and other interactions, must be involved subsequently.

Magnus-Levy [21] and Leathes [22] favoured the idea that C_2 units derived from hexoses might undergo a series of aldol condensations to yield intermediate products which, by simultaneous oxidation and reduction, could lead to the series of characteristic straight-chain saturated natural fatty acids which always contain an even number of carbon atoms in their molecules. A hypothesis of this nature accounts very well for the biosynthesis of the saturated acids, in regard both to their even-numbered carbon content and to the almost universal appearance of more than one even-numbered homologue among the saturated acids of seed fats (*v. supra*). A building-up process from C_2 units may thus reach a maximum at a preferred carbon content determined by the species, but a certain amount of overshooting to the next even-numbered homologue, and a similar failure to reach the preferred content by one or even more C_2 units, is regularly observable.

We have seen, however, that saturated acids are but a minor feature of the whole range of seed fats, and that it is unsaturated acids of the C_{18} series which vastly preponderate in nature. If all the primary natural fatty acids were saturated (as suggested by the previous hypothesis), this would demand a very selective and profound desaturation process to account for the overwhelming production of oleic, linoleic, linolenic, and other unsaturated acids in seed fats. This is on general grounds an unlikely sequence of events, and it seems in any event to be definitely ruled out by the now well-authenticated observation that the seeds of many plants produce fats containing higher proportions of their more unsaturated component acids when grown in cooler climates: in other words, on the desaturation hypothesis, more intensive desaturation must be involved the lower the temperature at which the biosynthesis proceeds. This has led to the conclusion that these most characteristic and abundant unsaturated acids may be produced by an entirely different

mechanism from that by which the saturated acids are synthesized. This divergence of synthetic mechanisms is sufficiently important to justify some slight further consideration here. Ivanow [23] first noticed that a given species of seed (linseed) yields oil of a more unsaturated character when grown in a comparatively cold locality. Subsequently, this has been observed in the case of many other annual species, and some recent studies on linseed and sunflower seed oils may be quoted here. Table II illustrates the extreme variations observed by Painter and Nesbitt [24] in a long series of observations of two varieties of flax grown in many localities in North America. Table III gives similar data for sunflowers grown in different parts of Africa, and also for the African seeds when grown side by side in England [25]; table IV shows the composition of sunflower seed oils from the variety 'Sunrise' [26] grown in different latitudes in Australia.

These and many similar observations suggest strongly that the formation of the unsaturated acids is a closely connected sequence of operations which may be indicated by the scheme:

TABLE II

Linseed oils grown in Minnesota, U.S.A., and Saskatchewan, Canada

Variety	Bison	Bison	Redwing	Redwing
Locality	Minnesota	Saskatchewan	Minnesota	Saskatchewan
Component acids (% wt):				
Saturated	11	9	10	8
Oleic	31	22	23	17
Linoleic	18	15	15	18
Linolenic	40	54	52	57

TABLE III

Sunflower seed oils from seeds grown in Africa and England

Source of Seed	Component acids (% wt) in oils from seeds					
	Grown in Africa			Grown in England		
	Saturated	Oleic	Linoleic	Saturated	Oleic	Linoleic
Southern Rhodesia	14	14	72	9	20	71
Tanganyika (S. Province)	14	21	65	9	22	69
Nigeria (Zaria)	12	30	58	11	15	74
Tanganyika (Kongwa)	12	31	57	11	24	65
Tanganyika (Lake Province)	13	43	44	9	21	70

TABLE IV

Sunflower seed oils (var. 'Sunrise') grown in Australia

State	Northern Territory	Queensland		New South Wales	Victoria
Latitude	$14\frac{1}{2}°\,S$	$26\frac{1}{2}°S$	$27\frac{1}{2}°S$	$32°\,S$	$36°\,S$
Component acids (% wt):					
Saturated	15	13	13	15	15	16
Oleic	54	51	37	30	27	19
Linoleic	31	36	50	55	58	65

Carbohydrate precursors of fatty acids

Linolenic $\downarrow$

$$CH_3.CH_2.CH=CH.CH_2.CH=CH.CH_2.CH=CH.$$
$$\downarrow \quad [CH_2]_7.CO_2H$$

Linoleic $\quad CH_3.[CH_2]_4.CH=CH.CH_2.CH=CH.$
$$\downarrow \quad [CH_2]_7.CO_2H$$

Oleic $\quad\quad\quad CH_3.[CH_2]_7.CH=CH.$
$$[CH_2]_7.CO_2H$$
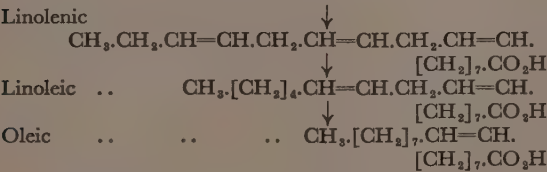
According to this hypothesis, formation of the less unsaturated from the more unsaturated acids might be expected to proceed less far in seeds matured at a lower than at a higher temperature, and this is in harmony with the observations discussed above. At all events, the observed facts point definitely to entirely distinct synthetic processes being concerned in the elaboration on the one hand of the predominant and characteristic

unsaturated acids, and on the other of saturated acids. The approximate constancy of the proportions of saturated acids present in seed oils in which the relative amounts of the unsaturated acids may vary through extremely wide ranges is indeed remarkable, and in itself is almost conclusive evidence of the essential distinctness of the respective processes concerned.

The recurrence of the C_3 unit ($=CH.CH_2.CH=$), and of sequences of saturated chains containing six or nine carbon atoms, in the unsaturated seed fatty acids prompts the thought that the latter may possibly arise not from C_2 units but from C_6 (hexose, E. Fischer [27]) or C_3 (pyruvic acid, Smedley [28]) groupings. This, however, is somewhat

remote speculation, in view of the existing lack of definite experimental evidence. The biogenesis in plants of fats from carbohydrates remains indeed an uncharted and mysterious field. We may now dimly recognize that the predominant unsaturated series of C_{18} acids come by one route, and the typical but less abundant saturated acids by another. But we are as far as ever, it would appear, from knowledge of how it happens occasionally that quite unusual unsaturated acids appear in preference to linoleic or linolenic acids—some

acids, like the latter, belonging to the C_{18} series, and others with different numbers of carbon atoms in their molecules. Most interesting and least understood of all is the manner in and by which species with common morphological relationships produce qualitatively the same mixtures of fatty acids in their seeds, so that classification of species according to the constituent acids in their seed fats leads to much the same result as that developed by the botanical classifications of Linnæus and his successors.

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Cybo d'Hyères: a fourteenth-century zoological artist

A. C. CROMBIE

Little is known of the Cybo d'Hyères to whom are attributed a number of early biological illustrations, some of which are here reproduced. He flourished in the fourteenth century, when there was widespread interest in the naturalistic representation of animals and plants. Though executed for decorative purposes, these illustrations are of value in informing us of the extent and accuracy of contemporary knowledge of the morphology of living organisms.

Uniquely among the sciences, biology has always been intimately associated with the pictorial arts. Aristotle's zoological books seem originally to have included anatomical drawings, and a magnificent collection of classical drawings of plants has come down to us in the so-called *Juliana Anicia Codex* at Vienna—a text of Dioscorides, with considerable additions, written about A.D. 512. The drawings in this manuscript appear to have been copied by a Byzantine artist from earlier manuscripts going back perhaps to Cratevas (physician to Mithridates), in the second century B.C. [1]. The revival of science after the Dark Ages saw also a revival of naturalistic illustration as early as the beginning of the twelfth century. Of the examples preserved in British collections of this new interest in accurate observation of nature for its own sake, none is more striking than the set of zoological drawings in the three late fourteenth-century fragments of Italian provenance attributed to the shadowy Cybo d'Hyères. These fragments (MSS *Additional* 27695 and 28841, and *Egerton* 3127) were acquired by the British Museum in 1867, 1871, and 1934 respectively.

Down to the thirteenth century, the chief interest of western Christendom in plants had been for their medicinal properties, and in animals for their symbolism in moral and spiritual teaching. St Augustine, especially, whose writings were perhaps the most powerful influence in forming the Latin mind before the thirteenth century, regarded the natural world as a sacrament, an outward and visible sign of truths of another order than the natural. The Moon was the image of the Church reflecting the divine light; the wind a symbol of the Holy Spirit; the sapphire bore a resemblance to divine contemplation; and the number eleven, which 'transgressed' ten, representing the ten commandments, stood for sin. This preoccupation with symbols was reinforced by the allegorical zoology of the *Physiologus*, a Greek work of Alexandrian origin written in the second century A.D., in which tales about animals were used to illustrate points of Christian doctrine. The phoenix was the symbol of the risen Christ; the ant-lion, born of the lion and the ant, had two natures and so was unable to eat either meat or seeds: it perished miserably like the man who tried to follow both God and the devil. The *Physiologus*, which was translated into Latin in the fifth century, and later into many other languages, became the source of all the illustrated western bestiaries.

Alongside this world of symbols, scientific biology became effectively established in the thirteenth century. By the early twelfth century a writer like Adelard of Bath, who had been in contact with Arabic learning, could assert that, besides exhibiting God's will, things also had a natural reason that was open to human investigation: here in fact he was only emphasizing another aspect of the teaching of St Augustine, who had invited Christians to see in the orderly and intelligible operations of the creation a manifestation of the Creator. But the main source of the new systematic revival of science was the corpus of Greek and Arabic scientific texts, especially Aristotle's works, which had become available in Latin translation by the beginning of the thirteenth century.

Of the scientific biology of the thirteenth century, Albertus Magnus's writings on botany and zoology are outstanding examples. They not only contain accurate descriptions of the external anatomy and habits of many plants, and of animals ranging from insects to birds and mammals, but go intelligently into general biological questions of ecology and reproduction, in answering which Albertus carried out some simple experiments. Other biological writings of the time are equally scientific in spirit. The early thirteenth-century writer Thomas of Cantimpré certainly

included in his *De Natura Rerum* a whole book about fabulous creatures in addition to the books describing his own observations, but the admirable text and illustrations of the Emperor Frederick II's 'Art of Falconry' are strictly confined to real and living animals. Several biological works of the period were written to be useful. Walter of Henley wrote on agriculture, and the treatise on this subject written by Peter of Crescenzi early in the fourteenth century remained a standard work for three hundred years. Of the herbals, the main purpose of which was to describe medicinally valuable plants in such a way that they could be easily recognized, the outstanding thirteenth-century example is that of Rufinus, which has recently been edited by Lynn Thorndike. Travellers at home and abroad also showed an intense curiosity about creatures of all kinds. Albertus Magnus himself, whose duties as Provincial of the German Dominican province took him long distances on foot, gave an account in his *De Animalibus* of whaling and fishing, and of German agricultural life; and the Icelandic *Konungs Skuggsja* or *Speculum regale* describes whales, seals, and walruses. William of Rubruck and Marco Polo brought back from Asia descriptions of new creatures, of the wild asses of Siberia, and of rice, ginger, and fat-tailed sheep.

Because of the way in which books were reproduced by copying, the illustrations included in both botanical and zoological works were often stylized copies of earlier versions, which sometimes went back even to classical times. However, from as early as the manuscript of the 'Herbal of Apuleius', written about 1120 at Bury St Edmunds [2], plants were drawn directly from nature. The late twelfth-century British Museum MS *Royal 12C* has naturalistic illustrations of ants and bees. From that period, naturalistic drawings and paintings of living creatures increased steadily in quantity and accuracy, both as illustrations in works of scientific biology and as decorations which might bear no relation to the subject-matter of the text. Of the former, the illustrations in Frederick II's 'Art of Falconry' are an outstanding thirteenth-century example. The sketches of a lobster, a fly, parrots, a lion 'copied from life,' and other creatures, that are found mixed up with studies in perspective, and designs for engines of war and industry, in the notebook of the thirteenth-century French architect Villard de Honnecourt, were the idle drawings of a versatile observer [3]. For the most part, the naturalistic illustrations of animals made in the thirteenth and fourteenth

centuries were decorative in intention. They were the product of close and accurate observation, but they accompanied no text, assisted no scientific exposition: they were contemplative rather than explicative. In appropriate contexts, close observation might be directly inspired by religious symbolism, but the religious motive increasingly freed itself from specific symbols and found expression in the contemplation of nature as a whole. 'I am moved,' said Vincent of Beauvais, 'with spiritual sweetness towards the Creator and Ruler of this world, because I behold the magnitude and beauty and permanence of His creation' [4]. In the naturalistic carving that stands out so freshly from the capitals, bosses, and misericords of the great Gothic churches [5], as well as in the fifteenth-century Flemish and French illustrated borders, we can see accurate observation made of things as they are, because God made them so and is shown through them all. It is to this class of accurate decorative illustrations that belong the biological paintings in the manuscripts attributed to Cybo d'Hyères.

The three fragments in the British Museum are written on plain vellum, each page measuring about $6\frac{1}{2} \times 4$ in. MSS *Additional* 27695 and 28841 contain fifteen and seven leaves respectively, and MS *Egerton* 3127 two leaves. Each leaf has been used on both sides. The illustrations are executed in clear line, tinted with colours and gold paint. Internal evidence shows them to have been done in Genoa or its neighbourhood [6]. The original book contained two Latin texts, and the scheme of decoration is different in each [7]. The first text, to which belong MSS *Additional* 27695 and *Egerton* 3127, and the first leaf of *Additional* 28841, is a treatise on the vices, written in prose by a member of the Cocharelli family of Genoa for his children. The tales with which he illustrated the theme he attributed to his grandfather, Pelegrino Cocharelli [6]. The same authority is cited in the second text, a history in loose rhythmical verse of Sicily in the time of the Emperor Frederick II (1194–1250), as *de Cocharellis vir nobilis nomine dictus Pelegrinus* [6]. This text is found in MS *Additional* 28841.

The prose treatise contains a series of full-page paintings illustrating the text, and most of the text pages themselves are framed in purely decorative borders. Inset in these borders are roundels containing miniature scenes with paintings of insects, birds, mammals, and grotesques. Minute studies of these creatures are used also for line fillings. The birds are the most popular group, and are
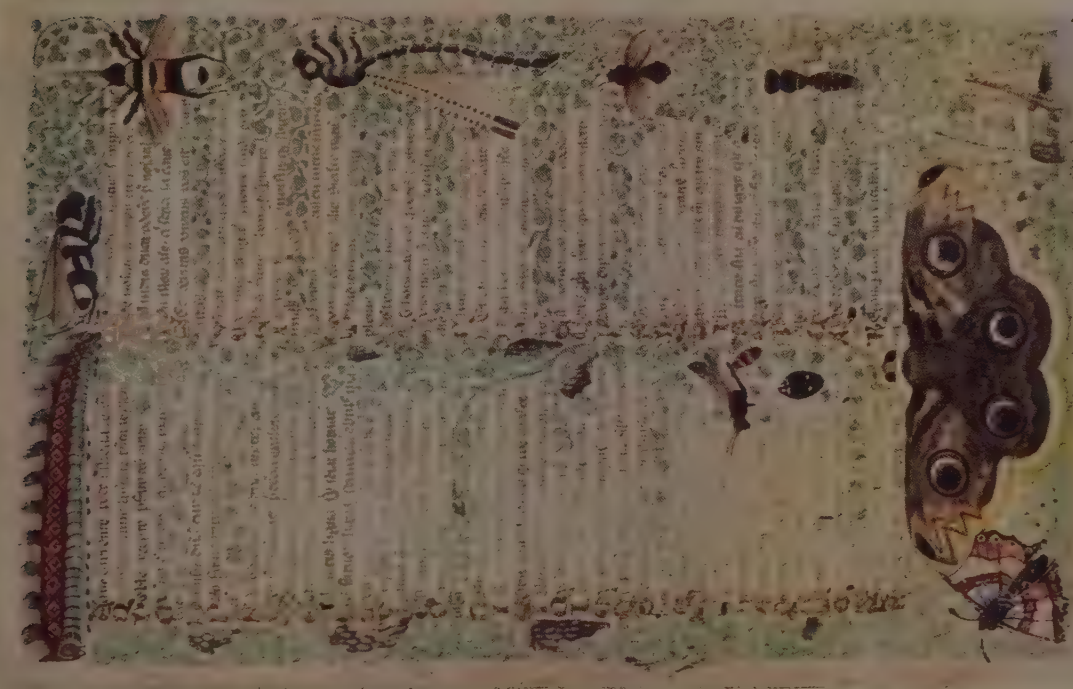
FIGURE 1 – *MS Additional 28841, f.4. Beginning top left, and reading clockwise round the margin:* 1. caterpillar, uncertain, possibly Lasiocampid moth; 2. probably same as 3; 3. bumble bee, Bombus ruderatus Fab. (?); 4. dragon-fly; 5. Psychid moth (?); 6. wasp, gen. Crabro; 7. immature grasshopper, gen. Pholidoptera (?); 8. great peacock moth, gen. Saturnia pyri; 9. butterfly, unidentified. *Reading down centre:* 10. Ichneumonid wasp, gen. Gravenhorstia; 11. carpet beetle, Attagenus pellio.
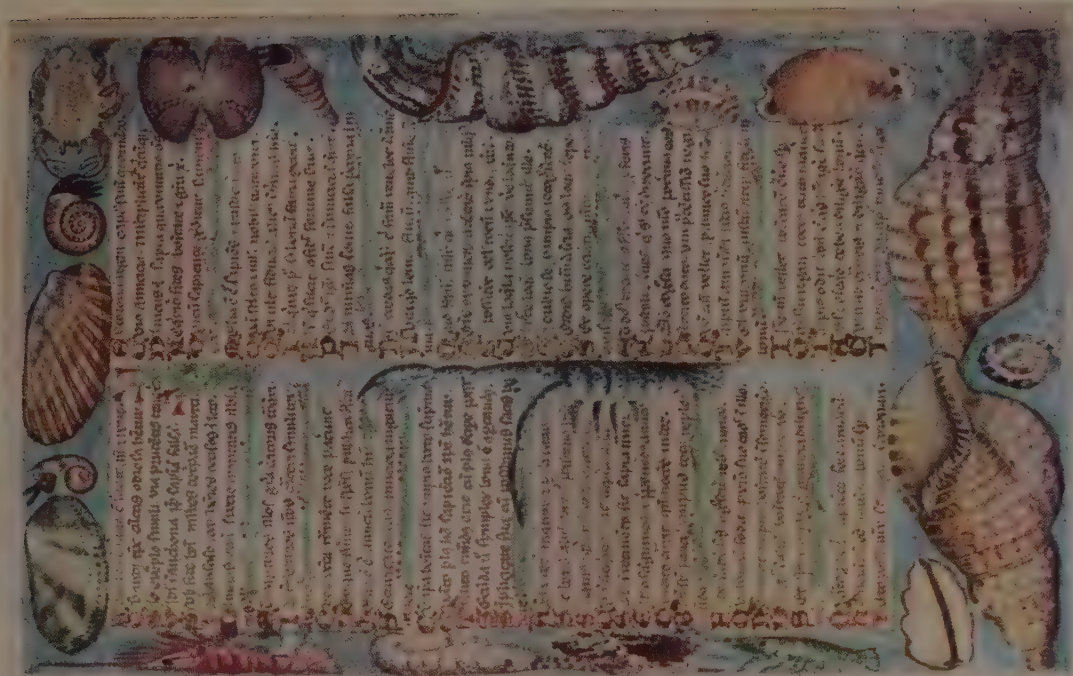
FIGURE 2 – *MS Additional 28841, f.5. Beginning top left, and reading clockwise round the margin:* 1. bivalve mollusc, Tapes pullastra; 2. gasteropod mollusc (?); 3. bivalve mollusc, gen. Arca; 4. nautilus; 5. spider crab, gen. Mithrax; 6. Tapes pullastra; 7. hermit crab in Turritella shell; 8. hermit crab; 9. pecten, gen. Glaber; 10. cowrie shell, Cypraea lurida; 11. whelk, Charonia tritonis; 12. limpet, Patella vulgata or lusitania; 13. Charonia tritonis; 14. Cypraea moneta; 15. shrimp, gen. Hippolyte; 16. lobster, gen. Homarus or Palinurus; 17. prawn, gen. Leander. *In centre:* 18. lobster, gen. Homarus.

FIGURE 4 – *MS Additional 28841, f.7⁰. Beginning top left, and reading clockwise round the margin:* 1. *two ladybird larvae;* 2. *spider with small moth (?);* 3. *spider;* 4. *lizard;* 5. *fly, Musca (?);* 6. *scorpion;* 7. *spider with small moth (?);* 8. *spider with fly (?);* 9. *longhorned grasshopper, gen. Ephippiger;* 10. *centipede.*

Acknowledgments. I wish to thank Mr N. D. Riley and his assistants at the British Museum (Natural History), and Dr J. Smart, Professor J. E. Smith, Mr H. L. G. Stroyan, and Dr W. H. Thorpe, F.R.S., for their help in identifying the animals illustrated in the figures.

FIGURE 3 – *MS Additional 28841, f.1. Beginning top left, and reading in the medallions clockwise round the margin:* 1. *goose (?);* 2. *quail;* 3. *owl, Athena noctua (?);* 4. *mallard;* 5. *goose;* 6. *peacock (?);* 7. *cock;* 8. (?); 9. *stork;* 10. *large duck, possibly merganser;* 11. *heron (?);* 12. *osprey (?) attacking cormorant (?);* 13. *hoopoe (?);* 14. *lion fighting bear;* 15. *stag;* 16. *lion killing doe. Reading down columns of text, left-hand:* 17. (?); 18. *eagle killing stork;* 19. *falcon killing duck;* 20. *kittens. Right-hand:* 21. *magpies and rabbit;* 22. *finches, possibly hawfinch;* 23. *lizard;* 24. *snake;* 25. *rabbits;* 26. (?); 27. *kittens.*

often quite well drawn (figure 3). Sometimes the miniatures match the subject of the text itself, as for example in *Egerton* 3127, where scenes of slaughter and mutilation accompany a discussion of the vice of treachery. A marked feature of the full-page paintings is the evidence they show of oriental influence: for example, in a picture of a Tatar khan, illustrating gluttony [8] and in a hawking scene [6]. This influence could have come through the great oriental trade of Genoa [9].

In the verse treatise the illustrations are all in the borders, which are not contained in a formal frame. Sprays with leaves and fruit, and sometimes grass and water, stray between the lines across the whole width of the column. Interspersed throughout are paintings of insects, arachnids, marine invertebrates, reptiles, and mammals. There are no birds. In contrast with the lively scenes in the other text, these illustrations are careful impressionistic studies with no dramatic content. There is a general tendency to put together on the same page animals traditionally allotted to the same group: for example, land quadrupeds, marine invertebrates (mostly crustaceans and molluscs), and a group containing insects and arachnids (figures 1, 2, 4) [10]. The last is by far the artist's most popular group, and some of his drawings are accurate enough to permit identification of the species.

Of the Cybo d'Hyères to whom these illustrations are attributed, practically nothing is known. It is not even certain that all the illustrations are by the same hand [6], [11]. No doubt the monk of Hyères was a member of the well-known Cibo or Cybo family of Genoa [6], [9], [12]. He flourished towards the end of the fourteenth century. A name by which he seems to have become known was *Monaco delle Isole d'Oro* [13], and he may have been a monk of St Honoratus, a monastery on the island of Lérins or Lerino, off the coast of Provence. He seems to have lived also on one of the neighbouring islands of Hyères [14]. The artistic genesis of the painter of these fragments is equally obscure. In what school he learnt, what connections he may have had with other Ligurian painters, with the Tuscan school coming from Giotto, or with the Arabic world across the Mediterranean, are quite unknown. His proper connections with the past seem to be with such an artist as the illustrator of 'The Art of Falconry.' Looking forward in time, he is a precursor of the Venetian painter Andrea Amodio, who completed the illustrations for the herbal by Benedetto Rinio in 1410, of the Flemish miniaturists of the late fifteenth century [15], of Leonardo da Vinci, and of Dürer. All belong to that western tradition of illustration without which the rise of modern biology would have been impossible.

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The mode of action of hereditary factors

ADOLF BUTENANDT

Although research has thrown much light upon the nature of certain series of chemical reactions occurring in living organisms, we are still far from understanding how so many and such complex changes can proceed harmoniously within the tiny compass of a single cell. There is evidence that the ultimate co-ordinators of vital cellular processes are genes which, though probably not themselves of an enzymatic character, produce or control enzymes.

The way in which a living cell reacts to external and internal conditions depends upon its hereditary constitution. The latter is determined by the arrangement of hereditary factors, known as genes, within the nucleus. The genes, collectively known as the genome, have the following characteristic properties:

1. They are situated at definite points on the chromosomes.

2. They can duplicate themselves in cell division, thus ensuring that the hereditary constitution is passed on unchanged to daughter cells.

3. They are very stable, but not completely so; they can pass from one stable state to another. By such mutations the hereditary constitution may be varied in a new generation.

4. They determine the characteristics of the individual. Each gene controls certain external characteristics (phenes) and the genome determines the characteristics of the individual as a whole.

Genetic research having established the qualities of genes, the task of the biochemist is to answer the following questions:

1. What is their chemical structure, and how can this structure explain their mutability and their ability to reproduce?

2. How do genes act, and by what chains of reaction do they govern the external characteristics of the individual?

These biochemical problems have been investigated during the last decade, but it has not so far been possible to determine in a general way the substance and structure of genes. Wherever genes occur, there are also found characteristic substances having the properties of nucleoproteins. It seems highly probable that these nucleoproteins are closely linked with the genes, for it is known that they are contained in all living matter capable of reproduction.

The elucidation of the enzymatic processses of metabolism, and the isolation of many specific enzymes, led the way to the experimental investigation of gene action. It is now known that each step in the metabolic changes which determine the life-processes is made possible by the action of specific enzymes. Investigation of the biochemistry of gene action revealed a close relationship between hereditary factors and enzymes. Genes act through enzymes, and experimental results make it appear probable that every gene has its specific associated enzyme. This knowledge leads to important conclusions, which will be dealt with later.

The methods and reliability of this type of research may be demonstrated by the detailed description of one chain of gene action; as an example the experimental analysis of the gene-linked pigment formation in the eyes of insects has been chosen. The results were obtained by co-operation between the Max Planck Institutes of Biology (A. Kühn) and of Biochemistry (A. Butenandt).

Kühn and his school performed an experiment which is of fundamental importance for the investigation of gene action. In the wild race of the flour-moth (*Ephestia kühniella*) the eyes of the imago, and the eyes, skin, and some other organs of the caterpillar, are dark brown in colour. The colouring is produced by the formation and accumulation of certain pigments, the ommochromes. By spontaneous mutation of a single gene, a race can be produced which is distinguished from the wild race by the absence of ommochromes. The mutation-race has, to a large extent, lost the ability to form pigment; thus the eyes of the imago are pink, and the caterpillar shows practically no pigmentation at all. The ommochrome-forming gene of the wild race will be denoted by v^+, and the mutation is defined

as the transition of the gene v^+ into its allele v. In the original work the gene of the wild race is denoted by A or a^+, the mutated gene by a. The denotations v^+ and v have been adopted to bring this work in line with that done on *Drosophila*.

If organs of the wild race are transplanted into the penultimate stage of the caterpillar of the pigment-lacking race, or if aqueous alcoholic extracts of v^+ tissue are injected, the v race acquires the ability to form ommochromes. The caterpillar develops normal pigmentation and the eyes of the imago become coffee-coloured, i.e. the typical external appearance of the wild race is produced. The tissues of the wild race therefore contain an extractable substance which is formed only under the influence of the v^+ gene, and which interposes itself between gene and external characteristic. The chemical analysis of this substance, and the elucidation of its relationship with the gene on one side and the pigment on the other, provided the first chance for an experimental analysis of the mode of action of a gene.

It was possible to prove that the substance

duration of action of the kynurenine, but is directly proportional to the dose of kynurenine administered. The amounts of kynurenine absorbed and of pigment produced are of the same order. It may therefore be concluded that kynurenine does not act as a catalyst in the pigmentation process, but helps in synthesizing the pigment molecule: it is a chromogen. Kynurenine thus represents one link in the chain of substrates leading to the pigment. The ommochromes may be regarded as derivatives of tryptophan, and kynurenine is an intermediate in the process leading from tryptophan to the pigments.

The question now arises as to the relation between kynurenine formation and the gene v^+. In mammals, the degradation of tryptophan to kynurenine takes place by the action of tryptophan-pyrrolase, a specific enzyme found in the liver. Recent research by Knox has shown this enzyme to combine the functions of a peroxidase and oxidase, and the mechanism by which tryptophan is transformed through formylkynurenine into kynurenine is probably as follows:

Tryptophan   *Formylkynurenine*   *Kynurenine*

which causes pigment formation under the influence of the gene v^+ is kynurenine, an amino-acid previously known as an intermediary product of tryptophan metabolism in mammals. Kynurenine is o-amino-benzoyl-alanine (II); it is contained in the urine of rabbits which, while being fed on rice, are given considerable quantities of tryptophan (I). The mammal is thus able to transform tryptophan into kynurenine; the same ability is found in numerous micro-organisms.

I.   *Tryptophan*   II.   *Kynurenine*

By determining the quantitative relation between the amount of kynurenine administered to the v mutant of the flour-moth and the amount of pigment produced, it was shown that the degree of pigment formation does not depend on the

It may be assumed that an enzyme corresponding to tryptophan-pyrrolase similarly catalyses the transformation of tryptophan into the chromogen kynurenine in the wild type of *Ephestia*. The transformation evidently cannot take place in the v mutant because its tissue lacks the enzymatic activity of tryptophan-pyrrolase. This fact provides important information about the action of the v^+ gene; its function consists in providing the organism with the active enzyme-system of tryptophan-pyrrolase. The mutation of the gene v^+ into v deprives the cell of its ability to achieve the normal enzyme-controlled conversion of tryptophan into kynurenine. Pigmentation is stopped because kynurenine formation is prevented. If the v mutants are then provided with this missing link in the reaction-chain, pigmentation must take place in a normal way.

Experimental evidence thus indicates that in the v mutants tryptophan will accumulate, as

there is no effective pathway for its degradation. This is actually so: the tryptophan content of the *v* mutants of the flour-moth has been shown by Caspari to be higher than that in the wild race.

The ommochromes formed from kynurenine are not uniform; they include low-molecular, alkali-sensitive ommatines and high-molecular, alkali-resistant ommines. In the flour-moth, the pigment of the retinula cells and the subsidiary pigment cells of the eye is an ommine (scotommine); the main pigment of the caterpillar is an ommatine; and the pigment cells of the cornea contain a third pigment, xanthommine. All three derive from kynurenine, are absent in the *v* mutant, and appear simultaneously after injection of kynurenine. The linkage of these different pigments to the same gene affords an explanation of a general phenomenon, namely that of one gene being responsible for the formation of several

extracts of the pupae of blue-bottles (*Calliphora erythrocephala*) and is now obtainable synthetically.

$$CO-CH_2-CH-COOH$$

3-*Hydroxykynurenine (III)*
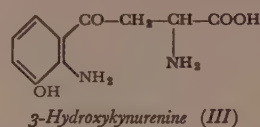
3-Hydroxykynurenine represents a further link in the chain of substrates joining tryptophan and pigment. Its formation from kynurenine depends on the action of a specific enzyme, which evidently acts only in tissues containing cn^+ genes.

Ideas developed for the gene v^+ can be applied to the mode of action of the cn^+ gene. Its presence enables the cell to prepare an active enzyme which transforms kynurenine into hydroxykynurenine, and it is now possible to establish a chain of gene-actions in the following way:

GENE v^+ cn^+

GENE-ENZYME v^+ enzyme cn^+ enzyme

SUBSTRATE

Tryptophan *Kynurenine* *Hydroxykynurenine* ----> *Ommochrome*
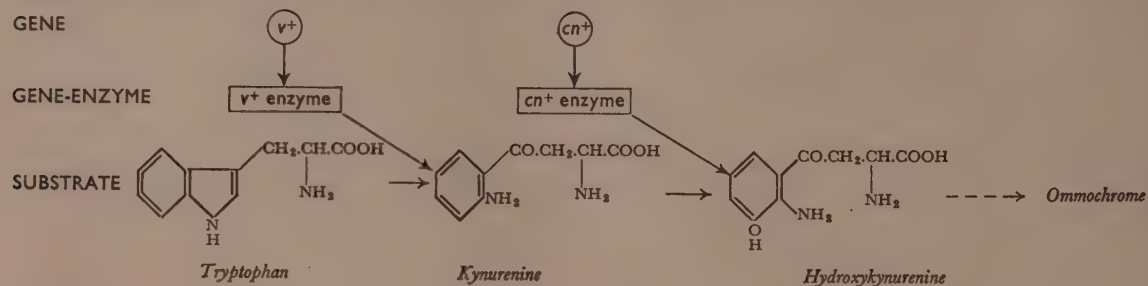
characteristics. In the above example, this phenomenon depends on the fact that the same precursor (kynurenine), formed by the action of the v^+ gene, is required for the synthesis of all three pigments. Later stages of pigment synthesis must then be directed differently in different cells.

Equivalent results have been obtained (Beadle, Ephrussi) for the fruit-fly, *Drosophila*; the dark red colouring of the eye of the wild race depends on the v^+ gene, the mutation of which to v strongly reduces the eye pigmentation. In this case, too, kynurenine can fully replace the action of the gene.

A similar effect on the formation of eye pigment is caused in *Drosophila* by the mutation of a second gene, denoted by cn^+. Its mutation into its allele cn also causes inability to form ommochrome. Transplantation and extraction experiments have shown that the gene cn^+ intervenes at a later stage of the pigment-producing process; its action requires the presence of the v^+ gene.

Biochemical analysis shows that the action of the cn^+ gene can be replaced by 3-hydroxykynurenine (III), which can be isolated from

The diagram illustrates the way in which genes intervene by means of enzymes at certain stages of the reactions leading to a substrate formation, and also the way in which different genes may act together to produce the same characteristic. Thus the formation of a single phene may depend on the presence of several genes.

The colouring matter in the pigment granules (produced from hydroxykynurenine by a reaction which is still unknown, but which probably proceeds by way of quinone formation) is linked to a protein-carrier apparently essential for the final stages of pigment synthesis. In flour-moths the formation of these protein granules is disturbed by the mutation of a gene wa^+ into wa, which completely interrupts pigment formation. The protein granules, shown to be present in v^+ and v moths by extraction of the pigment component with suitable solvents, are absent in the eye cells of the mutant wa. The pigment precursors, especially kynurenine and 3-hydroxykynurenine, are produced by the mutant wa; they cannot, however, be utilized by wa tissue. Investigation of the wa mutant has revealed a further

link in the chain of gene-actions leading to pigment formation. Here we find a relation to the problem of structure; the diffusible chromogens (kynurenine, hydroxykynurenine) may be present in all cells, but since pigment formation depends on their attachment to protein they accumulate exclusively in certain cells and tissues.

The combined action of the three genes in the formation of the pigment is illustrated in the accompanying diagram. Its significance as an example of the complementary action of several
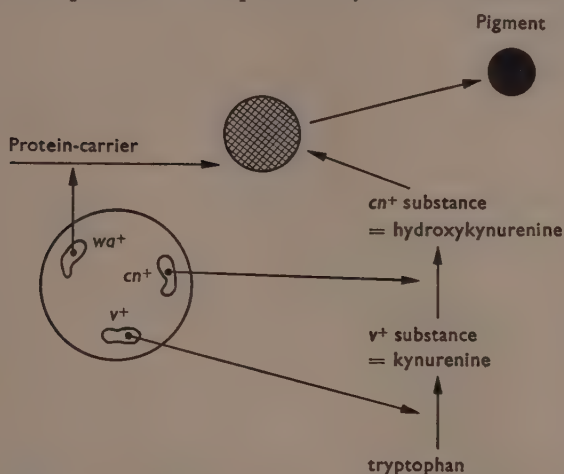
Diagram illustrating the action of the genes v+, cn+, *and* wa+ *in a pigment-forming eye cell.* (A. Kühn.)

genes is clearly discernible: 'In a chain of gene actions various gene-linked processes follow each other. The various chains meet, as it were, at the knots of a reaction network. In our case there is a series of conversions leading from tryptophan to the pigment precursor which is then linked to the protein granule, and the chain of gene actions (probably of many links) which synthesizes the carrier protein' (A. Kühn).

The preceding analysis of a chain of gene actions serves as an example of the methods of research which have afforded an insight into the mode of action of genes. It is also of historical interest, as it represents the first analysis, in the field of genetics as well as of chemistry, of a chain of gene actions proceeding through several intermediary stages. The conclusions drawn seem to be universally applicable, for similar results have been obtained in numerous other cases.

Among the earliest investigations of this kind may be mentioned the analysis of the gene-linked formation of plant pigments of anthocyanine-flavanol and chalkone character (Lawrence and Price). Pigment formation in the hair of rabbits

(R. Danneel) proceeds in a manner similar to ommochrome synthesis; the pigments here formed from various precursors are, however, of a different chemical type. Investigations by R. Kuhn and his collaborators, at the Max Planck Institute for Medical Research, Heidelberg, on the gene-linked synthesis of sexual substances in algae, afford a further example of the intervention of genes at certain stages of enzyme-controlled processes. The far-reaching work of Beadle, Tatum, and their collaborators on mutants of the red bread-mould (*Neurospora crassa*) have confirmed the view that genes intervene in the life-processes of cells by means of specific enzymes.

A direct and unexpected relation was established between the chain of gene actions involved in pigment formation in insects and a gene-controlled metabolism in *Neurospora*. It was found that *Neurospora* produces nicotinic acid—necessary for the energy-metabolism of all cells—from tryptophan. The first stages of the conversion of tryptophan to nicotinic acid are identical with the first steps in the conversion of tryptophan to ommochromes. In both cases the tryptophan is converted into kynurenine by gene action, and then, by the action of a second gene, into hydroxy-kynurenine. At this stage, however, a division takes place; the subsequent intermediates, leading to the synthesis of pigment or nicotinic acid respectively, are different. Hydroxykynurenine thus represents a key substance from which two chains of gene action branch off. Recent investigations (Neuberger) have shown that rats, too, produce nicotinic acid from tryptophan just as *Neurospora* does. It follows that the same biochemical principles—due probably to the same genes—apply to a variety of organisms.

Our introductory thesis that genes deploy their action by means of specific enzymes thus seems well confirmed. The established relations between gene and enzyme present, however, further possibilities for the elucidation of gene action:

1. The gene itself possesses the properties of an enzyme and catalyses gene-linked reactions.

2. The gene produces the enzyme either as a primary or as a secondary product.

3. The gene does not cause enzyme production but controls enzyme activity—for example, by the formation of specific activators or inhibitors.

It seems improbable that the genes themselves have an enzyme character. The solution of this

problem may, therefore, be given either by 2 or by 3; it may also be that these two mechanisms occur together. Further experimental analysis will help towards the solution of this problem, and may also usefully enlarge our knowledge of the nature of genes.

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Endeavour Prizes

The annual meetings of the British Association for the Advancement of Science, which have been held without a break—except during the last war —since 1831, are outstanding events in scientific circles in Britain. They are held in a different city each year, and during the week devoted to them several hundred lectures are delivered by men eminent in all branches of science. The meetings are widely reported by both press and radio, and thus are an invaluable means of communicating results of recent research not only to scientists but to the public in general.

The importance of interesting the younger generation in the work of the British Association is apparent, and in order to promote this interest ENDEAVOUR has, since 1950, offered a number of annual prizes for essays written in English on scientific subjects, the competitors being restricted to those under 25 years of age, without distinction of nationality or domicile. In addition to a monetary award, the prizes include the cost of attending the meeting of the British Association at which they are formally presented.

This year the meeting was held in Belfast under the presidency of Professor A. V. Hill. His Royal Highness the Duke of Edinburgh, last year's president, was also present, and for the second year in succession accorded us the honour of awarding the prizes to the successful candidates.

The subjects chosen for the 1952 essays were:

1. Sulphur in medicine, science, and technology.
2. Oceanography.
3. The origin of life.
4. The influence of climate on technology.
5. Scientific research in polar regions.
6. Gas discharge tubes.

The prizewinners were as follows:

1st Prize of 50 *guineas* to Miss A. Forrest, B.Sc. (24), assistant lecturer in zoology and research student in genetics in the University of Aberdeen, for an essay on 'The origin of life.'

2nd Prize of 25 *guineas* to Mr A. Gilchrist (24), Magdalen College, Oxford, for an essay on 'Gas discharge tubes.'

3rd Prize of 15 *guineas* to Mr R. V. Coates (20), of the University of Bristol, for an essay on 'Gas discharge tubes.'

In a special section for competitors under 18 years of age the following prizes were awarded:

A prize of 5 *guineas* to Mr I. N. L. Johnston (17), of Wallasey Grammar School, for an essay on 'The origin of life.'

A prize of 5 *guineas* to Mr S. J. Lam (17), an Indian pupil studying at Dulwich College, for an essay on 'Oceanography.'

Details of the competition and the list of subjects for 1953 will be issued shortly.

Parasitism, evolution, and phylogeny

THOMAS W. M. CAMERON

Comparative parasitology is a relatively new study, but it has already thrown so much light on vertebrate evolution as to leave no doubt of the desirability of pursuing it much further. A comparison of parasites—tapeworms, sclerostomes, and feather-mites—leaves, for example, very little doubt that the ostrich and the rhea had a common origin and, moreover, an origin different from that of the ratite birds of Australia. Dr Cameron also suggests that American opossums may not be so closely related to Australian marsupials as has usually been supposed.

The fundamental tenets of one theory of evolution are, first, that life is a single unit and that all animals are related, and, secondly, that those organisms survive which are best fitted to their environment. All animals now living are accordingly the descendants of forms which existed previously. If we possessed a complete set of fossils we should find that, far back in the past, there was a common ancestor. We do not possess, and can never hope to complete, such a series. Too often, from data obtained from comparative anatomy, from embryology, and especially from comparative osteology, we can merely guess at the relationships between groups of animals. However, extra data can be obtained from other sources, and among the most promising of these sources is comparative animal parasitology. Parasites, like their hosts, have been subjected to evolution, and their study can therefore give valuable information about the evolution of the hosts themselves.

Parasitism is an ancient phenomenon; it goes far back into geological time and has probably always been part of the general pattern of vertebrate life. In contrast, its scientific study is comparatively recent, and has been to a very great extent preoccupied with its economic importance and the part played by parasites in causing human and animal disease. Most parasites, however, are not naturally very pathogenic, and disease is largely man-made—and consequently recent. It is obvious that a virulent parasite will tend to eradicate its host and finally, therefore, itself. Accordingly, natural selection tends to eliminate virulent species, and to maintain those of low virulence which can obtain a livelihood from the host without doing it serious damage.

While it is true that some consideration has been given to the relationship between ectoparasites and the phylogeny of their hosts, very little attention has been paid to internal parasites, and only too often the emphasis has been misplaced.

Internal parasites are extremely common, and no vertebrates (and probably few invertebrates) are free from them. Many of them are extremely complex animals, with highly developed and often very specialized organizations. All at some time produce offspring which leave the host, spend an essential time outside, and return to a new host. In many cases, this external phase in the life-cycle has numerous very rigid requirements, with tremendous hazards and difficulties in the way of the entrance of the offspring into a suitable host. The external phase often includes successful passage through an intermediate host or hosts, and such parasites tend to occur in zoological groups which need not be related but have similar habits. Other parasites, with free-living stages able to move about and to penetrate the skin of the potential host, tend to infect animals with similar environmental surroundings. Those which re-enter the body as faecal contaminants of food tend to have a rather wide range of host species.

Among the older parasites, many have become too specialized to produce mutants capable of living in new species of hosts. They have, so to speak, exhausted their ability to adapt themselves to any but closely related hosts. A parasite depends during its parasitic stages on definite, essential, biochemical and biophysical conditions in the host animal. It is obvious that the physiological demands of the parasite must remain more plastic than those of its environment, otherwise it will die out and the species will disappear. As in other animals, there is a limit to this plasticity, which, moreover, tends to become reduced as specialization increases. As a result, many species have become extremely host-specific; some can live only in a single species of animal, others in a few related species. Comparative parasitology shows that this host-specificity appears to be a function of evolutionary age and specialization, and that the more host-specific a parasite is, the

more divergent it appears to be from its original phylogenetic stem. It can diverge only within its host, which itself may be more or less simultaneously diverging from its own original stem. Examination of these host-specific parasites should accordingly be of value in tracing the relationships of the host, and in supplementing the palaeontological evidence.

Host-specificity is a physiological attribute, but, so far, our only reliable method of recognizing its presence is by morphological characters—a criterion which is not completely satisfactory. It is abundantly evident that related hosts tend to have related parasites, but this statement is not without exceptions, particularly obvious among animals with similar habits, and there is sometimes in parasites a kind of convergent evolution more or less analogous to that seen in the hosts. Taking this into account, there still remains a considerable number of phylogenetic host-specific forms, especially among the sporozoan protozoa, the tapeworms, and certain groups of nematodes—forms which have apparently evolved *pari passu* with the host. Much of this kind of evidence confirms modern ideas on the relationship of vertebrates. Thus, malarial parasites (*Plasmodium* spp.) occur in reptiles and in birds, in insectivores and in numerous primates, and occasionally in rodents, but, apart from a few obvious cases, they occur in no other mammals. Their greatest incidence is found in birds, and there seems a probability that they were originally reptilian parasites in the Mesozoic period, and were able to survive only in that mammalian stem which led to the modern primates. Their occasional presence in rodents suggests that this group may have originated in the same stem.

A very similar situation is found among the pinworms (*Oxyuridae*). Disregarding the plainly erratic species in equines, pinworms are confined to primates, rabbits (*Leporidae*), rodents, reptiles, and amphibia, with two very specialized genera in American opossums (*Didelphinae*) and cobegos (colugos or 'flying lemurs') (*Cynocephalus*). While corresponding in general to the evolution of the malarial parasites [1, 2], there is a clear suggestion that the pinworms had an even earlier origin than in vertebrates, because a distinct but related group occurs in millepedes and insects—especially scarabaeid beetles and cockroaches. Apart from their specialized physiological requirements and life-cycles, all pinworms closely resemble free-living nematodes, and the species in arthropods may represent a separate evolutionary surge in the

middle Mesozoic rather than be descendants of a common ancestor of those now living in vertebrates. In either case they are probably very ancient parasites.

Some even more interesting examples occur among the bursate nematodes (*Strongylidae*), the group which includes the human hookworms and gets its name from the umbrella-like structure at the posterior end of the male. In some of these nematodes, the anterior end is modified to form a sucking cup which is utilized as an instrument for feeding on tissue, usually intestinal mucosa. The hookworms live in the small intestine, but living in the large intestine of a variety of grazing animals is a related family, called the sclerostomes from the large mouth cup found in its best-known members, which occur in horses.

The sclerostomes all have a similar life-history, the female laying thousands of eggs which hatch outside the body, giving rise to free-feeding, free-living larvae; these after a while moult, cease to grow, and remain more or less quiescent until swallowed. If a larva is swallowed by the appropriate host, it resumes its growth and develops to maturity. The hazards of such a life-cycle are enormous, and the number of eggs laid is correspondingly very large; the chance of any one particular egg being successful in completing its life-history is in inverse proportion to the total number of eggs laid. These large numbers of eggs of course increase the opportunities for mutants to arise, and most of the animals infested with sclerostomes harbour a number of closely related species.

These worms have a most peculiar host-distribution [3, 4]. They reach their greatest abundance and variety in elephants (*Loxodonta* and *Elephas*), in equines and rhinoceroses (*Rhinoceros*, *Ceratotherium*, *Diceros*), and in Australian marsupials [5]; there is none in American marsupials (opossums). Two species occur in the American tapir (*Tapirus*), belonging to genera found in elephants and rhinoceroses; there is none, however, in the Asiatic tapir. One rather isolated genus (*Eucyathostomum*) occurs in South American peccaries (*Tayassu*), deer (*Mazama*), and agouti (*Dasyprocta*), with a separate species in each host. No other sclerostome occurs in either artiodactyls[1] or primates, but a distinct and probably more modern group called the oesophagostomes does so, and is found both in the Americas and in the Old World. Several closely related

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[1] Artiodactyls are ungulate mammals with an even number of functional toes on hind and fore feet. Examples are sheep, ox, goat, antelope.
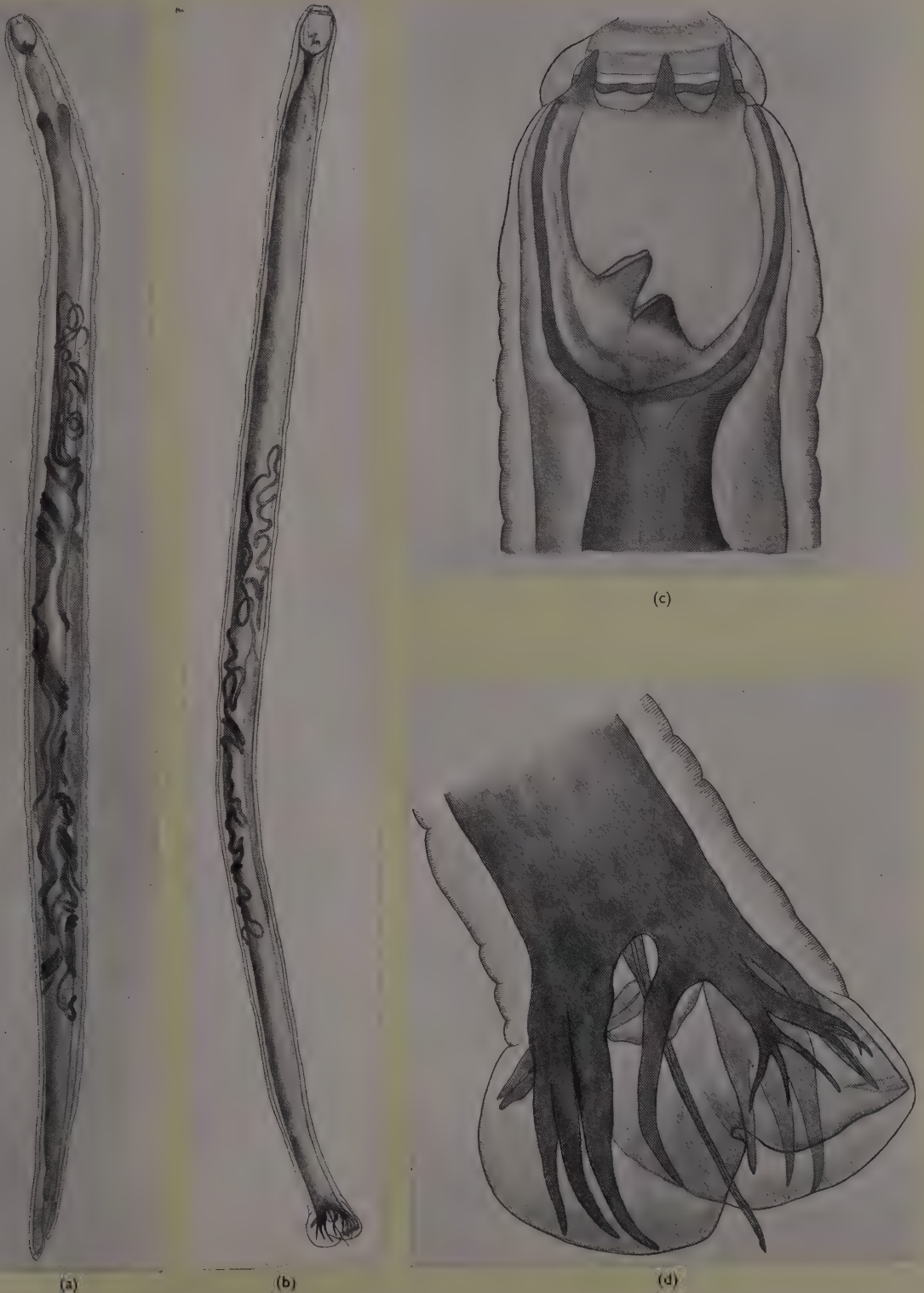
FIGURE I – *A typical sclerostome of the horse*, Strongylus equinus. (a) *Entire female* ($\times$ 6). (b) *Entire male* ($\times$6).
(c) *Head end, showing mouth-capsule, which attaches by suction to the mucous membrane, and by means of which the
worm feeds on tissue. The name sclerostome comes from this structure* ($\times$ 50). (d) *Bursa of male, a highly characteristic
sexual character, which gives the name to the entire group of bursate nematodes* ($\times$ 50).
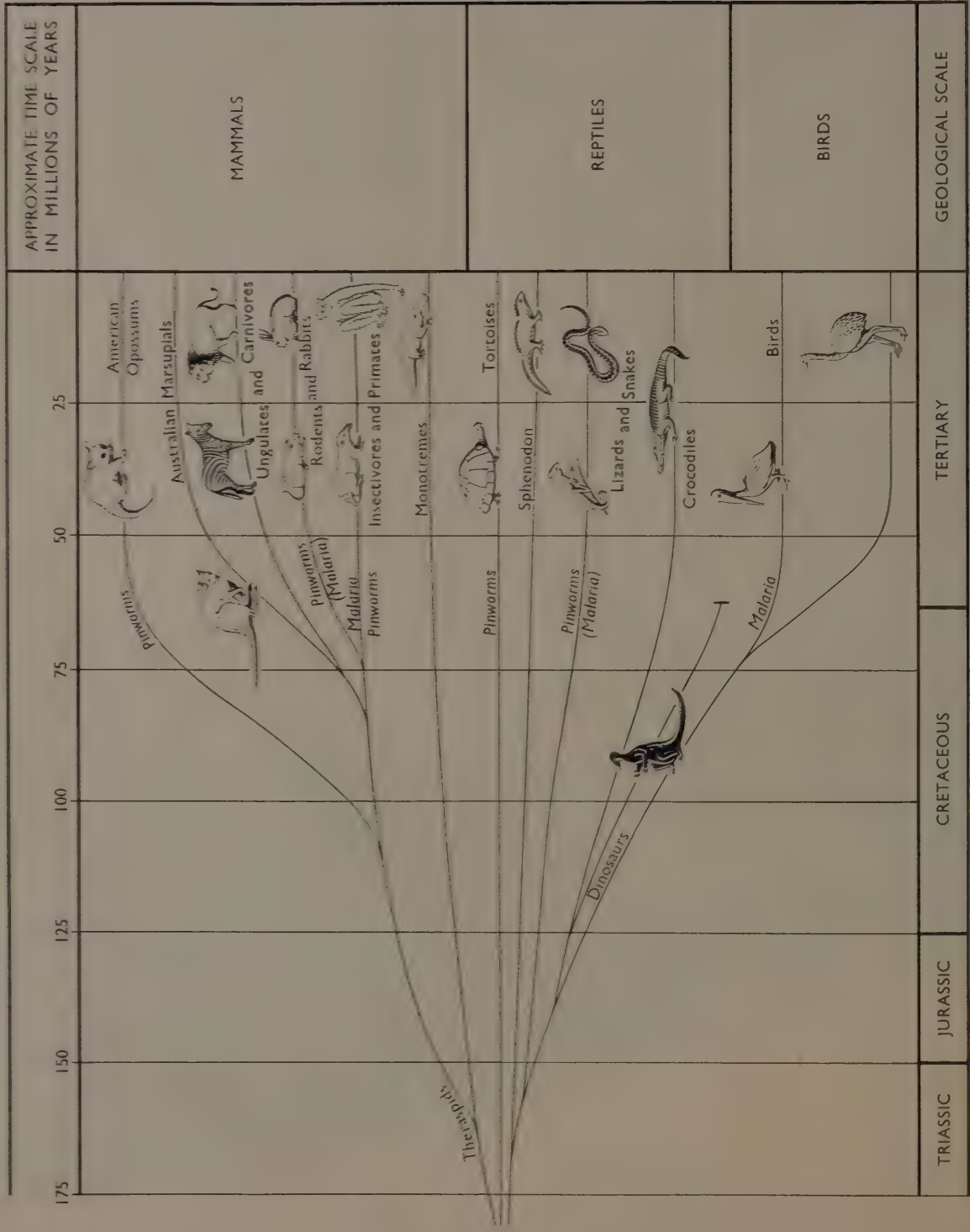
FIGURE 2 – The evolutionary relationships of the main group of vertebrates as suggested by their parasites.
(The geological scale and the classification of vertebrates follow Young and Simpson respectively.)
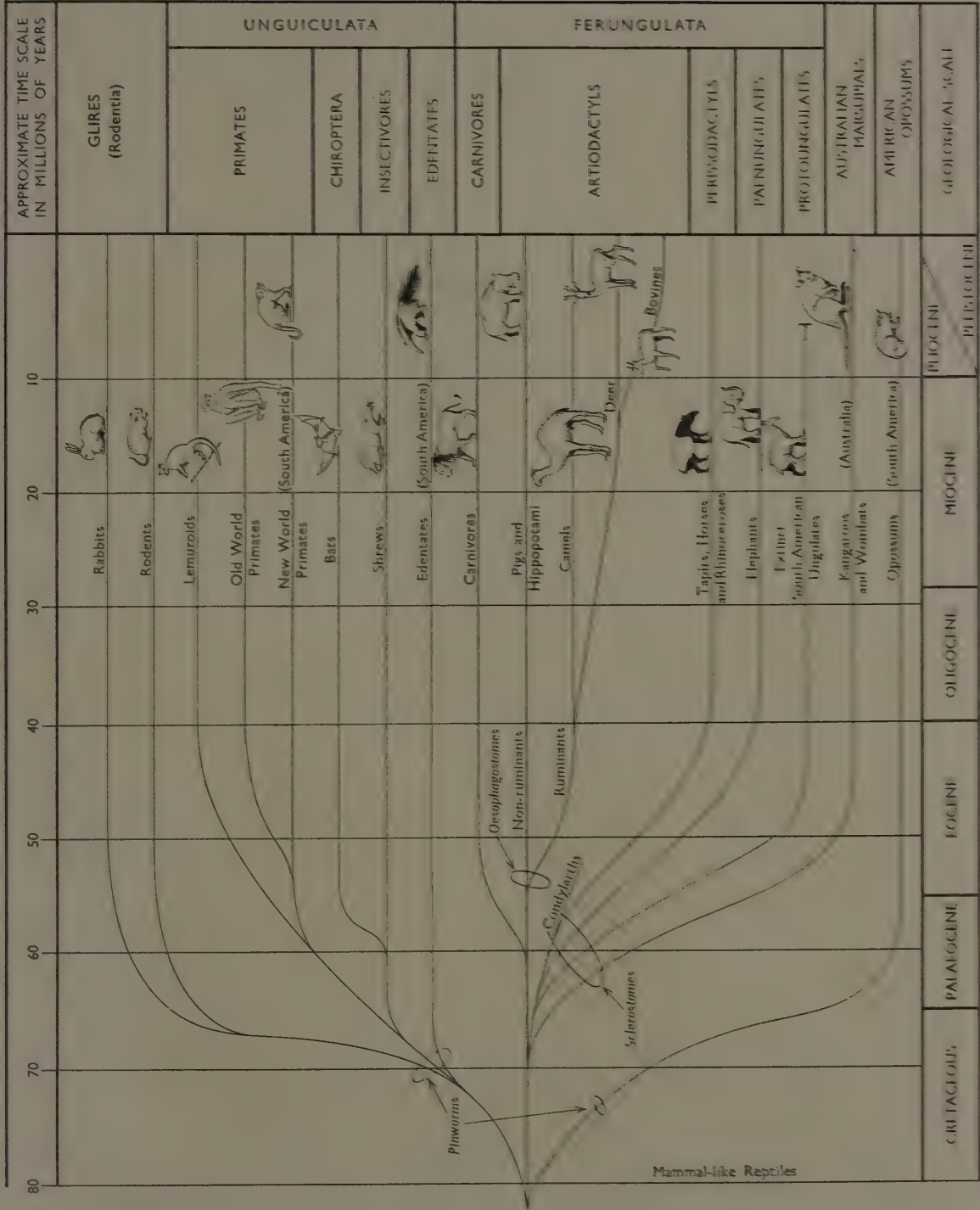
FIGURE 3—The evolution and relationship of the main groups of mammals as suggested by their parasites.

species of sclerostomes occur in the ostrich and the rhea, but none in any other birds; three species, also related to them, have been recorded from South American tortoises (*Testudo*), but none in other reptiles.

Two interesting lines of thought arise as the result of these facts, namely the relationship of the African ostrich (*Struthio*) and South American rhea (*Rhea*), which has long been known, and the relationship of the American opossums and the Australian marsupials, but before discussing them it is necessary to draw attention to the tapeworms.

The tapeworms reach their highest specialization in the birds, although they occur in all other groups of vertebrates as well. They are obviously very ancient and specialized parasites, without a trace of a digestive tract; it is doubtful if even their ancestors ever possessed one. They are mostly parasites of the small intestine, where they feed by absorbing, through their cuticle, non-specific carbohydrates from the food of their host, and specific nitrogenous compounds secreted from its intestine. In consequence, these worms usually have a high degree of host-specificity. This is especially evident in birds, where, as has been shown by Fuhrmann and others [6], each order (or even, occasionally, sub-order) has its own particular tapeworm fauna, differing from those of other (sub-)orders; this rule is so rigid as to be of value in avian taxonomy. The parasitic fauna remains constant even if the hosts are now separated by impassable barriers, suggesting an infection of avian hosts earlier than the great and sudden spreading of birds in Tertiary times. Now, the African ostriches and the South American rheas both harbour an identical species of tapeworm of a genus (*Houttuynia*) [7] which is found in no other birds, while the Australian cassowaries (*Casuarius*) and emus (*Dromaeus*) have tapeworms belonging to a cosmopolitan genus (*Raillietina*) which has representatives in all zoo-geographical areas.

The ostrich and the rhea have not only identical tapeworms and closely related sclerostomes, but their other parasites include two identical species of feather-mites: none of these parasites resemble those in other birds. It is difficult to avoid the conclusion that they not only had a common origin, but one separate from that of the ratite birds of Australia, i.e. the emu and cassowary. Moreover, the common origin was most likely in some portion of the ancient Africa, and may well have been earlier than that of other birds.

The case of the opossums and the Australian marsupials is more complicated, and the parasitological evidence does not seem to agree with the general belief in the relatively close relationship between these two groups; in fact, it suggests just the opposite. The entozoa of the opossums and the Australian marsupials are quite different. In the Australian marsupials there are fourteen genera of sclerostomes but probably no pinworms. In American opossums there are no sclerostomes, but a peculiar pinworm (*Cruzia*) is very common. Both opossums and the Australian marsupials possess tapeworms belonging to a somewhat primitive cosmopolitan family, but the species are different, the South American ones being the more primitive. Many of the genera of worms in the opossums are shared by the edentates and cebid monkeys, thereby indicating the relatively unspecialized nature of all three host groups, and agreeing completely with the hypothesis (not generally accepted) that the opossums and edentates represent relatively unaltered survivors of very primitive mammals, and the South American monkeys survivors of very primitive primates.

The great variety of bursate nematodes in the numerous Australian marsupials is undoubtedly associated with the secondary adoption of a terrestrial and a grazing habit, for infection is contracted by swallowing the larval stages on the ground. This probably happened late in the Eocene or even later, and quite probably in Australia. However, as there is also a considerable variety of sclerostomes in the more archaic ungulates (which never reached Australia), and as it is unlikely that there was a double origin of these worms, the marsupials must have obtained the ancestors of their sclerostomes before that time. As none occurs in native Australian rodents, there is a suggestion that they may have had at least a common habitat with these archaic ungulates, and perhaps a common origin with even more primitive ungulates, rather than with the opossums. The earliest fossil Australian marsupial dates from the Miocene, but the proto-marsupials must have entered the continent before then, probably from Asia, although there is no palaeontological evidence about the place or time. The marsupials possess no oesophagostome parasites, the modified sclerostomes which infect the more recent artiodactyls, and which have been successful in spreading to various other host groups (including the primates), thus giving evidence of considerable adaptability on the part of the parasites. As the artiodactyls had reached considerable proportions by the beginning of the Eocene, the

proto-marsupials might well have been expected to become infected if they had been exposed. This suggests that the latest date at which the proto-marsupials invaded Australia might have been the late Palaeocene. It may have been even earlier, and the sclerostomes of perissodactyls,[1] elephants, and marsupials may have a common origin in the extinct condylarths[2] of the Palaeocene; the marsupials may in fact be pre-placentals which developed in a different direction from the others, and which avoided the extended uterine development of the foetus.

The fact that condylarths reached South America, while sclerostomes are for all practical purposes absent from the original mammals there, does not rule out the possibility of the sclerostomes arising in the condylarths, or even in their ancestors. The ungulate groups which radiated from the condylarths in South America are all now extinct, and the genus *Eucyathostomum* with its three species—one each in an ancient rodent, a recent deer, and a recent peccary—may have originated in one of these extinct ungulates and have been transferred during the slight overlap of hosts after the modern mammals invaded South America but before the ancient ones became extinct. On the other hand, it is much more likely to have come from an invading mastodon from North America after the continents united in the late Tertiary.

If the Australian marsupials are not closely related to the American opossums, as has been supposed—and the absence outside Australia of fossil species related to the Australian forms agrees with this hypothesis—several interesting speculations arise. The degeneration of the milk teeth, the possession of an allantoic placenta in the bandicoot, the recently demonstrated relationship between the pouch, the scrotum, and genital hormones, and the different position of the pouch in different marsupials, are all in agreement with the suggestion that the Australian marsupials are descended from an ancestor which was on the way to becoming a placental. The Australian marsupials are far from primitive creatures, and the method by which the young are born is at least as specialized as that of the placentals, although in a different direction. It does not seem to be any less efficient than that shown by such modern placentals as mice, for example, where the young are born so undeveloped as to be a hindrance to the mobility of the parent. The fact that marsupials show certain anatomical characters which are closer to reptilian ones than similar characters in placentals does not mean that every character must be more primitive. Moreover, it throws doubt on the validity of the common dogma which still survives from early evolutionary days, namely that the absence of marsupials in other parts of the Old World is proof that the placentals are more efficient than marsupials, and consequently replaced them there. This thesis cannot be proved by the modern introduction of placentals to Australia and the consequent reduction of the native mammals; their destruction is directly or indirectly due to man—a relative newcomer in the world who could have had no destructive influence in early Tertiary times, but who since then has had an equally destructive influence on placentals in practically every part of the world.

It will be realized that these are mere speculations. Comparative parasitology is still in its infancy, and this very brief and superficial survey of some of its implications is necessarily incomplete and inconclusive. The available data impose strict limitations on the suggestions it may indicate. Better and more accurate morphological studies would strengthen the force of the suggestions and enable more definite hypotheses to be formulated. Special attention should be paid to the apparent exceptions, because they are the real clues, the real tests of the rules, and this requires a much greater enthusiasm for parasites than has existed in the past. However, such studies help to direct attention to the value of a true taxonomy, and to stress the importance of an ordered connection of all branches of biological science.

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[1] Perissodactyls are ungulate mammals with an uneven number of toes, e.g. horse, tapir, rhinoceros.

[2] Ungulates which became extinct in the Eocene, e.g. *Phenacodus*.

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Nucleoproteins and cell division

W. JACOBSON and M. WEBB

The main cytological changes which occur during cell division have long been familiar, but comparatively little is yet known of the accompanying chemical changes. By the use of highly specific staining and other delicate methods of analysis, however, the biochemistry of mitosis is slowly being revealed. Of particular interest, both theoretical and practical, is the discovery that a derivative of folic acid is essential for the fission of chromosomes.

The growth of every living organism is determined by the multiplication of cells. In unicellular organisms, division implies true reproduction, in the sense that two new individuals are formed from the original. Multicellular organisms, however, arise from a single primordial cell (the zygote), and it is the repeated multiplication of this cell and of its descendants which determines the development and growth of the individual.

Cell divisions are essential not only for the growing organism, but for the maintenance of the adult. Thus some tissues contain cells of a short life-span—for example, the cells lining the alimentary tract, and those of the blood and epidermis. These are steadily replaced by new cells, derived from divisions of young undifferentiated cells.

In a multicellular organism, the form of the constituent cells is extremely varied, since the different tissues are adapted to carry out specific functions and thus acquire particular characteristics. However, all cells possess in common certain features which are revealed by the microscopical examination of either living or specially treated (i.e. fixed and stained) preparations.

The direct observation of the anatomy of living cells is complicated by the fact that their internal structures generally do not absorb light, and thus exhibit little optical contrast under the ordinary microscope. The recent introduction of the phase-contrast microscope (Zernike [1]) has proved extremely valuable in the examination of living cells, as this technique increases the contrast between the intracellular structures.

Much useful information regarding the processes of cell division has been obtained from a study of cells grown in tissue cultures. According to this method, small pieces of tissue are transferred to a nutrient medium in a suitable glass vessel maintained at body temperature. Under these conditions, certain types of tissue grow in thin layers favourable for direct observation. In addition, such cultures usually show many cells in division.

When observed in the living state by ordinary transmitted light, a cell appears as an irregular translucent mass of protoplasm, within which is a pale spherical or oval body, the nucleus. The nucleus is bounded by a membrane which separates it from the surrounding cytoplasm. It contains a clear viscous fluid, the nuclear sap, about which very little is known, and one or more refracting spherical bodies, the nucleoli. In addition, a series of very fine threads, the chromonemata, may be just visible under the phase-contrast microscope (Fell and Hughes [2]). Within the cytoplasmic substance are various rod-shaped and spherical bodies, distinguished by their greater power of refraction. These include the mitochondria, small particles (microsomes, Claude [3]), and other inclusions such as fat-droplets, pigment granules, and vacuoles.

The same fundamental structures are seen in fixed and stained preparations as in the living cell. The nuclear membrane appears as a fine line delimiting the nucleus from the cytoplasm. Within the nuclear membrane the chromonemal threads and nucleoli may be demonstrated by various staining methods. Some of the dyes used for demonstrating the nuclear structures have a strong affinity for a group of chemical substances known as nucleoproteins.

The presence of nucleoproteins in the nuclei of animal cells was established towards the end of the nineteenth century. Thus in 1871 Miescher [4] isolated a nuclear constituent (nuclein) from pus cells and fish sperm. Miescher's nuclein was shown by Altmann [5] in 1889 to consist of an acidic, phosphorus-containing component, to which he gave the name of nucleic acid, in combination with a basic protein or proteins.

Following the extension of this work, principally by Kossel and Levene and their collaborators [26], it was generally assumed that the nuclei of animal cells contained deoxyribonucleic acid. It was not until the researches of Feulgen and Rossenbeck [6] in 1924, however, that the significance of the nuclear deoxyribonucleic acid became apparent. By means of a specific staining reaction with Schiff's reagent (fuchsin-sulphurous acid), these investigators showed that the chromonemata of resting cells contained deoxyribonucleic acid. Moreover, the discovery that the nuclei of plant cells, e.g. those of wheat embryo, gave the same reaction demonstrated that they too contained deoxyribonucleic acid. Before this time it was considered that plant cells differed from animal cells in containing only ribonucleic acid in their nuclei.

When it was found that deoxyribonucleic acid was confined to the cell nucleus, Feulgen and Rossenbeck suggested that ribonucleic acid was located in the cytoplasm. The presence of ribonucleic acid in the cytoplasm of different cells is now well established, both by chemical and by cytochemical investigations (e.g. Davidson [7]). This compound is responsible for the basophilic properties of the cytoplasm, and it is interesting that the association of (ribo-)nucleic acid with the cytoplasmic basophilia was suggested in 1913 by the experiments of van Herwerden [8]. He found that treatment of different types of cells with an enzyme (nuclease) preparation from spleen destroyed the cytoplasmic basophilia. More recently, an extensive cytochemical study in which ribonuclease was used in conjunction with selective staining methods (e.g. methyl green and pyronin) by Brachet [9] has established the relationship between the ribonucleic acid content and the basophilic properties of the cytoplasm.

ULTRA-VIOLET SPECTROPHOTOMETRIC INVESTIGATIONS

Both ribo- and deoxyribonucleic acid exhibit strong absorption in the ultra-violet at 2600A, which is characteristic of the conjugated double bonds of their purine and pyrimidine constituents. By virtue of this absorption, it is possible to determine with ultra-violet photomicroscopy the intracellular distribution of nucleic acids and certain other cell constituents. As early as 1904, Köhler [10] succeeded in photographing dividing cells in ultra-violet light by means of a microscope with quartz lenses, while ultra-violet photographs of cells in various stages of division were obtained by Lucas and Stark [11]. Ultra-violet absorptiometric methods for which light of different wavelengths was used were developed by Caspersson [12], and now provide a valuable method of investigating cell structure.

The ultra-violet absorption technique has the disadvantage that it does not distinguish between ribo- and deoxyribonucleic acid, but this limitation may be overcome by the fact that the two types of nucleic acid can be differentiated by various staining reactions. For example, the presence of ribonucleic acid in the nucleolus was inferred from the fact that this body gave a negative Feulgen reaction, and yet exhibited absorption in ultra-violet light at a wavelength characteristic of nucleic acid (Caspersson and Schultz [13]). A similar conclusion was reached by Brachet [9], from a study of the staining reactions of cells before and after treatment with ribonuclease.

In the nuclei of animal cells, the protein moiety of the deoxyribonucleoprotein is either a histone or, as in the spermatozoa of some species, a protamine. In addition to the basic protein component, a second protein which contains sulphur (Meyer and Gulick [14]) and tryptophan (Stedman and Stedman [15], Mirsky and Pollister [16]) has been isolated from some resting cell nuclei. According to Mirsky and Ris [17] this protein, which may represent part of the chromonemata, is linked to a relatively small percentage of nucleic acid, four-fifths of which is ribonucleic acid. It may be mentioned, however, that the ribonucleoprotein of the nucleolus is not accounted for in this work.

CELL DIVISION

Cell multiplication takes place in a similar way in most animal and plant tissues. First, the nuclear material of the cell divides by the complex process of mitosis, and this is followed by the cleavage of the cell body into two daughter cells, each containing one nucleus.

The main features of the mitotic changes occurring in the nuclear material have been recognized for over seventy years. Figure 15, taken from Klein's 'Atlas of Histology,' published in 1880, illustrates most of the essential steps in an almost correct form.

One of the first visible changes in a cell preparing to divide appears within the nucleus. The chromonemata begin to thicken and become increasingly more refringent (figure 3, P). These changes characterize the prophase of mitosis. The thickened threads (figures 3 and 4) are the
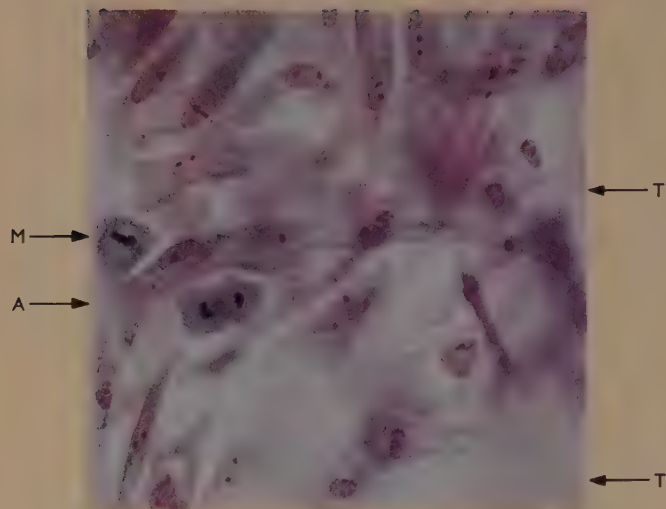
FIGURE 1 – *Numerous 'resting' cells and four in division.* M, *metaphase*; A, *anaphase*; T, *telophase.* (*Two daughter cells in each telophase.*) (× 425)
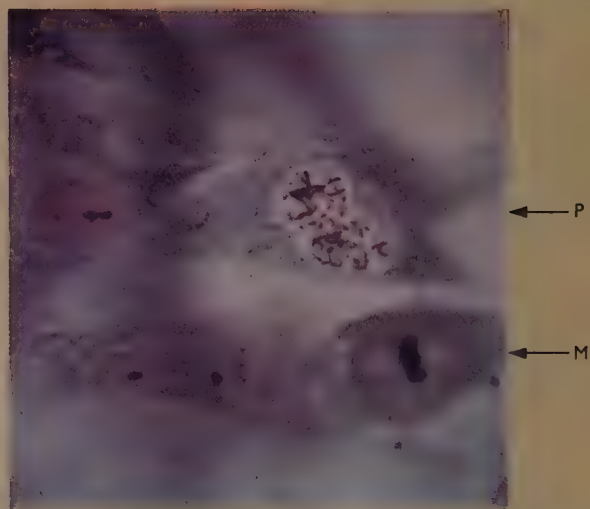
FIGURE 2 – *In the prophase nucleus* (P) *most chromosomes are purple-red, a few are dark blue-black.* M, *metaphase* (*the chromosomes stained black are seen in side view*). (× 1100)
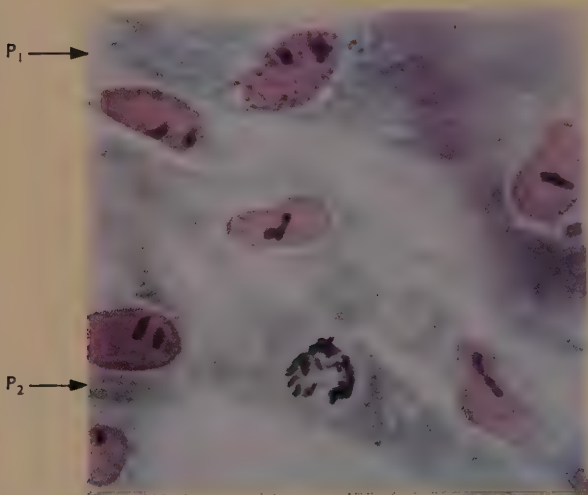
FIGURE 3 – P₁, *early prophase with purple-red stained chromosomes.* P₂, *late prophase; nearly all chromosomes are dark blue-black.* (× 1100)
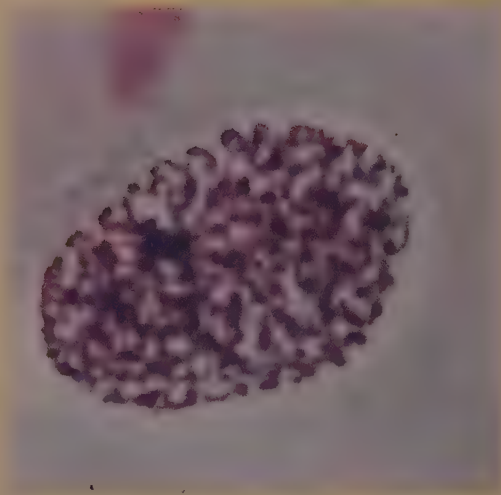
FIGURE 4 – *Early prophase nucleus of an amphibian cell. A few chromosomes are stained dark blue.* (× 1100)

FIGURE 5 – *Metaphase in surface view; the chromosomes are stained dark blue-black.* (× 825)
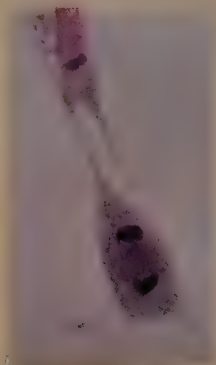
FIGURE 6 – *Anaphase; blue material between the two groups of chromosomes. Cytoplasmic inclusions appear pink.* (× 825)
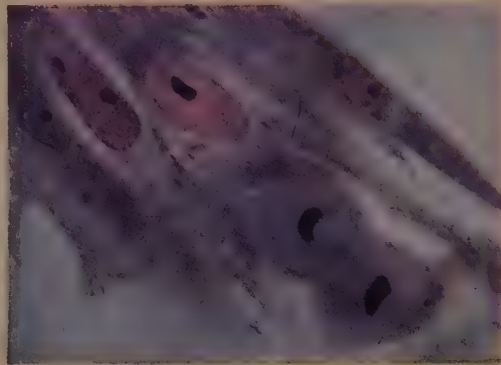
FIGURE 7 – *Anaphase. Note blue material in the cytoplasm between the two groups of chromosomes.* (× 1100)
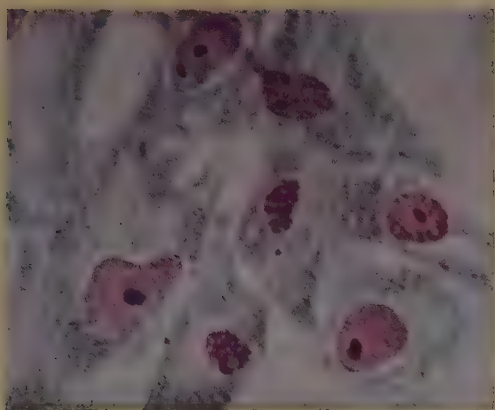
FIGURE 8 – *The two cells with the small nuclei represent a telophase. Most of the chromosomes stain purple-red. Blue-stained nucleoli appear in both nuclei.* (× 1100)

FIGURE 9 – *After digestion with ribonuclease the cytoplasm and nucleoli fail to stain blue; metaphase chromosomes stain purple-red.* (× 1100)

FIGURE 10 – *After digestion with ribonuclease the cytoplasm and nucleoli are colourless. Anaphase chromosomes stain purple-red.* (× 825)

FIGURE 11 – *After digestion with deoxyribonuclease all purple-red staining material has been removed, while nucleoli and cytoplasm remain blue. In the prophase nucleus (P) only those chromosomes are apparent which contained blue-staining material. In the anaphase (A) the chromosomes are stained blue. Note the blue matter between the two groups of anaphase chromosomes.* (× 825)
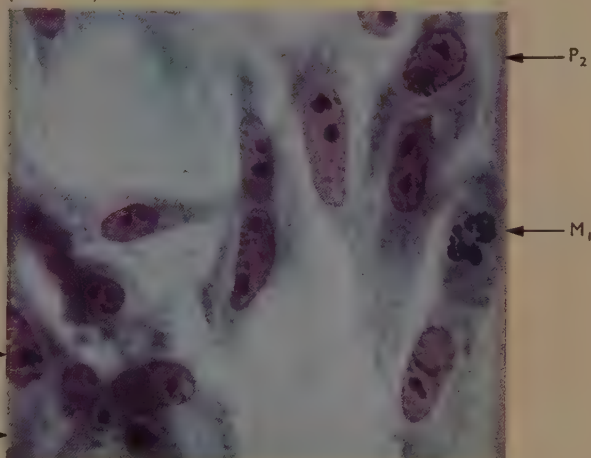
FIGURE 12 – *Effect of a folic acid antagonist (aminopterin, 1 : 2000 for 15 minutes). The chromosomes of a cell in metaphase (M_2) are clumped into a tight cluster (compare with a normal metaphase as in figure 5). Note that neither resting cells nor prophases (P_1 and P_2), nor the early metaphase (M_1), have been affected.* (× 915)
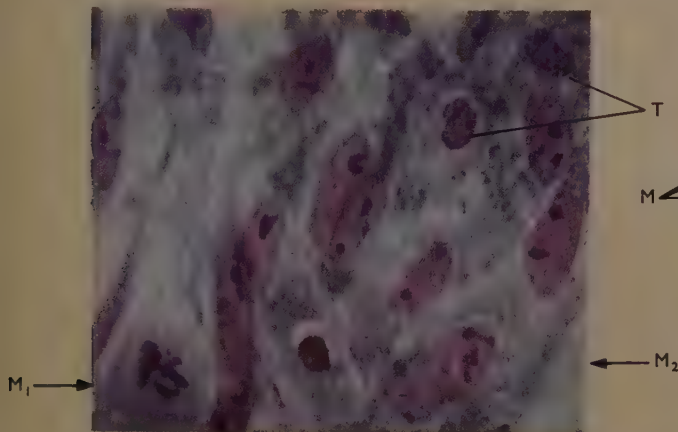
FIGURE 13 – *Effect of a folic acid antagonist (aminopterin, 1 : 2000 for 15 minutes). M_1 and M_2 are two cells in metaphase with clumped chromosomes. Two normal daughter cells at the end of telophase (T).* (× 915)
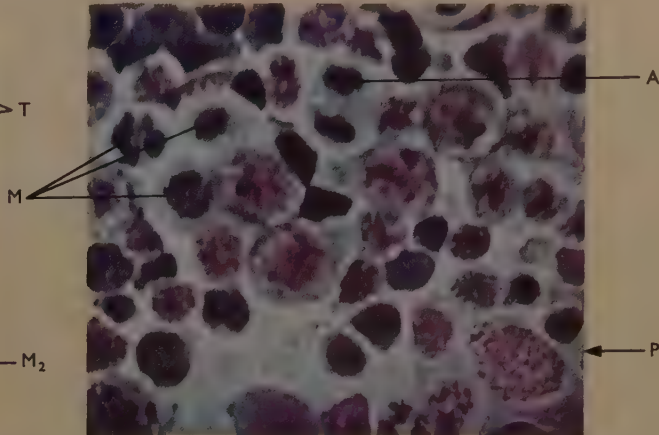
FIGURE 14 – *Bone marrow of a leukaemic mouse two hours after injection of 1 mg aminopterin. The five cells with large round nuclei are resting leukaemic cells. Dividing leukaemic cells: P, prophase; M, three cells in metaphase, all of which show clumping of the chromosomes. A, anaphase.* (× 915)

GRAPH 1 – *Percentage distribution of prophases* (P), *metaphases* (M), *anaphases* (A), *and telophases* (T) *among dividing cells growing in tissue culture.*
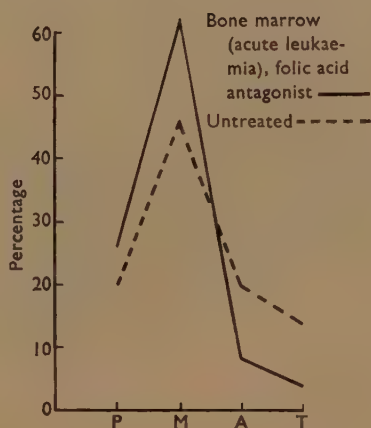
GRAPH 2 – *Percentage distribution of the four phases of mitosis among dividing leukaemic cells from a patient with acute leukaemia.*
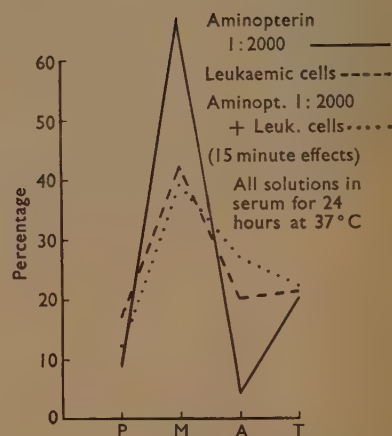
GRAPH 3 – *Percentage of the four phases among dividing cells growing in tissue cultures: curves after treating with: aminopterin* (——); *supernatant of a leukaemic cell suspension* (-----); *a mixture of the two* (·······). *Aminopterin has been inactivated by the leukaemic cells.*

chromosomes, and at this stage their shape varies from coiled or bent threads to short rods, depending on the type of cell. In some cells it can be observed that each chromosome is double, being composed of two finer threads or chromatids, which lie closely approximated throughout their length (figure 15, *d*). The chromosomes of different species vary in size; thus those of mammalian and avian cells are usually small and those of amphibian cells much larger (compare figures 3 and 4). Simultaneously with the prophase-changes in the nucleus, the cell tends to become rounded in shape.

At the end of prophase the nuclear membrane disappears (figure 3, P_2), and the chromosomes, now lying free in the cytoplasm, begin to move towards the equator of the cell. This represents the beginning of the second stage of cell division, the metaphase, which is characterized also by the disappearance of the nucleolus (figure 1, *M*; figure 2, *M*; figure 5).

During metaphase, the chromosomes contract further, thicken, and arrange themselves horizontally in a plate across the equator of the cell. By this time the area of the cytoplasm above and below the equatorial plate has become orientated into the so-called spindle, which in figure 2 is seen as a clear area on each side of the group of chromosomes. In some fixed preparations, the spindle area of the cytoplasm shows fine threads converging towards each cell pole, and, in the living cell, polarized light reveals a longitudinal orientation of the protein molecules in this area (Swann [18]).

In the next stage of cell division, called the anaphase, the two chromatids of which each chromosome is composed separate longitudinally, so that they become independent. The separated chromatids, or daughter chromosomes as they are now called, then move along the spindle fibres towards the cell poles (figures 6 and 7; see also figure 15, *h–l* and *p–t*). At the same time, the cell stretches longitudinally; this movement takes only a few minutes. By the end of anaphase, each group of chromosomes may be arranged in a tightly packed cluster, around which a nuclear membrane is re-formed; the chromosomes lose their contracted form, and the nucleoli reappear in each daughter nucleus (figure 1, *T*, and figure 8). During telophase, which is the final stage of mitosis, the cytoplasm divides by constriction in the equatorial plane, and thus two daughter cells are formed.

THE NUCLEOPROTEINS OF THE CHROMOSOMES

Although the cytological aspects of mitosis are now fairly clearly defined, little is known of the nature of the chemical changes and enzymatic reactions associated with cell division. The behaviour of the nucleoproteins during mitosis has been followed both by cytochemical methods and by ultra-violet absorption technique. The cytological observation that the chromonemata of the resting nucleus give rise to the prophase chromosomes has been interpreted as a condensation of the nuclear deoxyribonucleohistone from a dispersed state on to the contracting chromonemata, while the observed changes in the structure of the chromosomes during telophase are attributed to the redispersion of the nucleohistone. The details of these changes, and also of the disappearance of the nucleoli in prophase and their reappearance in each daughter nucleus in telophase, are not clearly understood.

Brachet [19], Frolova [20], Kaufman, McDonald and Grey [21], and Turchini [22], have produced evidence that, during mitosis, ribonucleoprotein is present on the meta- and anaphase chromosomes in the cells of certain plant and invertebrate tissues, as well as in the egg-cells of some amphibians. The behaviour of ribonucleoprotein in the division of cells in birds and mammals has been studied by the present authors [23]. In this work it was noticed that when cells were treated with May-Grunwald's and Giemsa's dyes, the structures in the resting nucleus which contain deoxyribonucleoprotein stained purple-red, whereas the nucleolus and cytoplasm which contain ribonucleoprotein stained blue. During mitosis, however, only pro- and telophase chromosomes
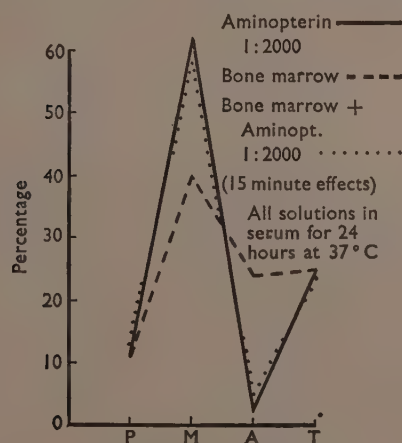
GRAPH 4 – *As graph 3, but with normal bone marrow instead of leukaemic cells. Note: Normal bone marrow has not altered the effect of aminopterin.*

were found to stain purple-red like the chromone-mata of the resting nucleus, while meta- and ana-phase chromosomes appeared dark blue-black. This result indicated that meta- and anaphase chromosomes contain some other component in addition to the deoxyribonucleoprotein. The fol-lowing experiments showed that this additional component was ribonucleoprotein:

1. Isolates of ribo- and deoxyribonucleoprotein, when spread on a slide and treated in the same way as the tissue, stained blue and purple-red respectively.

2. The cells were digested with (a) deoxyribo-nuclease and (b) ribonuclease. These enzymes specifically depolymerize, and thus render soluble, the corresponding nucleoprotein. It was found that the deoxyribonuclease removed the purple-red-staining material from chro-monemata and chromosomes. Thus most of the prophase and telophase chromosomes could not be stained, while the meta- and anaphase chromosomes stained bright blue (figure 11). Ribonuclease, on the other hand, removed all blue-staining material from the cytoplasm and the nucleolus, and the chromosomes in meta- and anaphase stained purple-red, like those of pro- and telophase (figures 8 and 9). Thus it was concluded that meta- and anaphase chro-mosomes contain both types of nucleoprotein.

It was also noted that the cytoplasmic area through which the two groups of anaphase chro-mosomes had moved stained darker blue than any other part of the cytoplasm, as if the anaphase chromosomes begin to shed their ribonucleo-protein while passing through the cytoplasm (fig-ures 1, 6, 7, and 11). The spindle fibres, which do not contain ribonucleoprotein, can be seen as colourless threads within this blue staining matter. Recently, H. G. Davies [25] has succeeded in re-cording in the living cell the presence of increased amounts of ultra-violet-absorbing substance in the cytoplasmic area through which the anaphase chromosomes have moved (figure 16). When, in telophase, the nuclear membranes are re-formed around the two groups of chromosomes, the blue-staining material can still be traced in the cyto-plasm, outside the nucleus.

As the appearance of ribonucleoprotein on the chromosomes, and its possible transfer into the cytoplasm, may have considerable biological im-portance, this point was studied in greater detail. It was found that in prophase, just before the nuclear membrane and the nucleolus disappear,

small areas on some chromosomes already stain dark blue-black, while other parts of the same chromosomes are still coloured purple-red. Thus it is not likely that cytoplasmic ribonucleoprotein is adsorbed on to the chromosomes, nor would it be reasonable to assume that the nucleolar ribonucleoprotein might account for all the chro-mosomal ribonucleoprotein. The possibility has to be kept in mind that this material may be synthe-sized on the chromosomes.

CHEMICAL FACTORS INVOLVED IN CELL DIVISION

Very little is known about specific chemical substances functioning during cell division, but recent observations on the mode of action of folic acid antagonists have thrown some light on this problem.

Folic acid (formula I) is a vitamin essential for normal growth of the whole animal, and a de-ficiency in this factor leads also to a reduction in the number of white and red blood cells. Some analogues of this compound have an antagonistic action to folic acid, by interfering with its normal function. Examples of folic acid antagonists are aminopterin, 4-amino-folic acid (formula III), and A-methopterin, 4-amino,10-methyl folic acid (formula IV). These compounds have a clinical use, as they can induce temporary remissions in cases of acute leukaemia.

I. Folic Acid

II. Leuconostoc Citrovorum Factor

III. Aminopterin

IV. A-methopterin
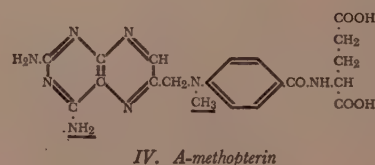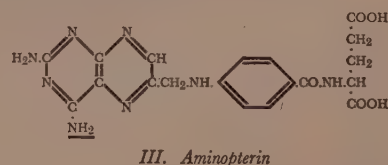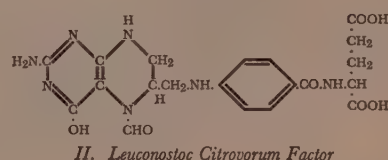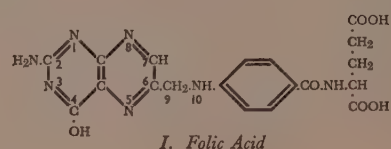
Folic acid antagonists prevent dividing cells from completing mitosis; the cells are arrested in metaphase (graph 1), and their chromosomes fail to split, forming a solid cluster in the middle of the cell (figures 13 and 14). This action is almost instantaneous, provided a sufficiently high concentration of the antagonist is applied. The early stages of division are not affected, and cells enter mitosis at a normal rate; non-dividing cells also appear to be unchanged.

When folic acid and a folic acid antagonist are applied simultaneously and directly to cells, even very high concentrations of folic acid fail to counteract the inhibitory action of the analogue. This indicates that it is not the function of the folic acid itself which is blocked. A derivative of folic acid, however, namely the *Leuconostoc citrovorum* factor, 5-formyl-tetrahydro-folic acid (formula II), proved able to neutralize the mitotic inhibition caused by folic acid antagonists [24].

From these experiments it may be concluded that the presence of the *Leuconostoc citrovorum* factor is essential for the splitting of the chromosomes, and that the step from metaphase to anaphase cannot be performed without it. It is interesting to note that the appearance of ribonucleoprotein on the chromosomes is not affected by folic acid antagonists, and that the arrested metaphase chromosomes retain their ribonucleoprotein.

It was mentioned above that folic acid antagonists can suppress the leukaemic process temporarily in some patients, by arresting the dividing leukaemic cells in metaphase (graph 2). Eventually, however, the mitosis of the immature white cells fails to be affected by the antagonists. The following experiments may throw some light on this resistance. If leukaemic cells (10 mg), taken from a mouse suffering from a leukaemia, which fails to respond to folic acid antagonists, are incubated *in vitro* with aminopterin (1 mg), the antagonist is converted into an ineffective substance. This can be shown by testing the supernatant fluid of the incubate on dividing cells grown *in vitro* (graph 3). On the other hand, aminopterin when incubated with the same quantity of normal bone marrow remains unchanged, as was demonstrated by the inhibitory effect of the incubate on the dividing cells in tissue cultures (graph 4). To search for antagonists which cannot so readily be changed by the leukaemic cells should be one of the foremost tasks in the attack on this still incurable disease.

Note on figures. All cells are stained with May-Grunwald's and Giemsa's dyes. The nuclei of resting cells are purple-red, nucleoli (in the nuclei) are blue. The cytoplasm appears blue.

Figures 1–3 and 5–13 show chick embryo cells (osteoblasts), grown in tissue cultures for 24–48 hours. Figure 4 is an amphibian cell from a tissue culture of the lung of the newt, *Triturus cristatus* (by courtesy of Dr J. N. Boss).

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Iron organisms

E. G. PRINGSHEIM

Everybody has occasionally seen scums or precipitates of ochre in wayside ditches, but few may have realized that their origin is due to the activity of small organisms. The uses of such deposits go far back into prehistoric times, the most ancient being the decoration of various objects, even the human body itself, with the help of ochre. Where greater quantities are available, as bog iron ore, they have been, and are, used as a raw material in iron-smelting. Their freedom from undesirable impurities is due to their biological origin.

It seems that Ehrenberg [9] was the first to analyse ochre deposits with the microscope, and to state that they are composed of residues deposited by certain organisms which he mistook for diatoms. His name *Gaillonella* (*Gallionella*) *ferruginea* for some such deposits of fossil material is, like so many of his names, still in use, although the organism itself was not found until much later, by Cholodny [2]. The description of an iron bacterium which is mainly responsible for the formation of bog ore was given by Kützing [10]. His *Leptothrix ochracea* also remained puzzling until a short while ago, although it is the most commonly mentioned of all iron organisms.

Of these, the first to be adequately described was *Crenothrix polyspora*, which Cohn [5], the founder of scientific bacteriology, discovered in wells where the water was unsuitable for consumption because of a brown, flocculent precipitate. Cohn gave a satisfactory description of the life-cycle of this bacterium, and used, for the first time under the microscope, the Prussian blue reaction with potassium ferrocyanide and hydrochloric acid. The original application of microchemical tests in plant physiology had been made by Sachs [19]. The Prussian blue reaction fulfils to perfection the requirements of such a test, since it differentiates even the finest structures, and stains them to various shades according to the concentration of ferric compounds present (figure 1).

The importance of biological methods in the hygienic investigation of drinking water was established in general by Cohn and his pupils, but the biochemical role of iron organisms remained obscure until Winogradsky's [21] famous little publication *Über Eisenbakterien*. The title marks a new advance, postulating a biological group of bacteria characterized by their relation to iron. This idea was based on culture experiments, resulting in the observation that such bacteria require almost no organic nutrients, and leading to Winogradsky's conclusion that iron bacteria utilize for their metabolism the chemical energy derived from the transformation of iron from the ferrous to the ferric state, and that they are therefore chemo-autotrophic.[1] This concept, of the greatest consequence, has been shown by Winogradsky himself and by others to be well founded for various groups of micro-organisms, but is not yet finally established for iron organisms.

Although Winogradsky's paper of 1888 is scholarly and impressive, it seems to have been too brief for its conclusions to be generally accepted. Molisch [13, 14] opposed it strongly: after having succeeded in growing one of the iron bacteria in pure culture, and in showing that it can live in much the same way as other bacteria, he wrongly concluded that Winogradsky was mistaken. In actual fact, he should have been content with having shown for the first time that chemo-autotrophic bacteria can also live heterotrophically.[2] All later authors took sides either with Winogradsky or with Molisch, without seriously attempting to decide the issue—with the exception of Lieske [11, 12], whose papers, however, are not as conclusive as is sometimes considered.

Besides bacteria, there are many other iron-depositing organisms, belonging to the flagellates and to the algae. To include them all, Gaidukov's (1905) general term, iron organisms, seems adequate. Many forms have unfortunately been given names without sufficient knowledge of their real nature, their inorganic deposits or incrustations being much more impressive and durable than the delicate organisms themselves. There is therefore a great deal of literature—for instance, communications by Naumann [15], Deflandre [7], Dorff [8], Beger [1], and others—describing structures the relation of which to definite species is not always known, with only casual reference to living

[1] Capable of self-nourishment on inorganic compounds.
[2] Obtaining nourishment from organic compounds.

cells. On the other hand, Cholodny [2, 3], Pascher in many of his papers, and others have given careful descriptions of organisms with inorganic brown deposits containing iron, and of the way in which the deposits are exuded and shaped. Cholodny was able to show by careful observation that the structure known as *Gallionella* and by other names is actually only the excretion of a bean-shaped bacterium. The same author also published (1926) a monograph on the morphology and physiology of iron bacteria, while the present writer has published a paper on iron flagellates [16], and two on iron bacteria [17, 18], in which the nature of the hitherto misinterpreted deposits, and the great changeability of these organisms, are discussed.

MORPHOLOGY

The iron organisms as an ecological group are, in spite of their taxonomic diversity, unified by their ability to deposit on their surface morphologically defined structures mainly composed of inorganic material and containing a high percentage of ferric compounds. The liability to be greatly modified by surrounding conditions, which they seem also to have in common, is connected with their ability to exist without producing these deposits; in that state they have often been mistaken for quite different organisms. Contrary to previous expectations, the characteristic deposits were found to be non-essential parts, and their formation was shown to depend on factors not directly connected with indispensable metabolic processes. This explains why extraordinary variation of appearance is possible without a correspondingly great difference in growth.

Among the different organisms, the range of shapes of deposit is as wide as their taxonomic diversity. In bacteria, they occur as tube-like sheaths in the members of the genera *Sphaerotilus* (figures 2, 3) and *Crenothrix*, as twisted ribbon-shaped stalks in *Gallionella* (figure 4), and as roundish capsules in cells. living singly or in clusters. Trichomes of *Myxophyceae* (blue-green algae) sometimes have iron-impregnated sheaths, and other filamentous algae, particularly *Hetero-kontae*, adsorb iron on their holdfasts, while some *Chlorophyceae* deposit it on their cell-walls. The greatest variety is found in flagellates. *Euglenineae*, *Chlamydomonadaceae*, and others have envelopes almost completely composed of inorganic precipitates. *Anthophysa* and *Siderodendron* produce branched stalks in a way similar to those of *Gallionella*, while *Bikosoeca* (figure 1) and others have goblet-shaped

envelopes of iron compounds around their naked cells.

In all these organisms there is, in one and the same species, a wide variety of appearance according to conditions. *Sphaerotilus natans* Kütz., for instance, thrives in great tassels on solid substrata covered by dirty running water. These tassels are composed of filaments of bacterial cells held together by slimy tubular sheaths. The latter may become softened and dissolved, releasing *Pseudomonas*-like swarmers (figure 3). The same organism grows in a quite different state in quiet waters with only a little organic matter, forming branched filamentous structures, the sheaths of which are not slimy. It has then been called *Cladothrix dichotoma* [6]. A third form is produced when ferrous compounds and very little organic substance are present. The sheaths become brittle and glass-like in appearance, by deposition of ferric hydroxide in a hard, colloidal form. This is the old *Leptothrix ochracea*, which looks ochre-coloured in bulk, but never brown under the microscope.

The flagellate colonial *Anthophysa vegetans* Stein is not always found in the stalked spherical clusters pictured on the left of figure 5. In water deficient in iron and manganese it may occur in stalkless free-swimming spherical colonies, to which the name *Monas sociabilis* Meyer was given, or in single cells by disintegration of colonies; it would then be a *Heterochromonas* Pascher if derived from the variety with an eye-spot, or a *Monas* if belonging to the variety without this feature.

Species of *Trachelomonas* (figure 6) have a spherical, ovoid, or rather long rigid envelope around a euglenoid cell-body; it is usually brown with manganic admixture in a ferric matrix. When iron and manganese are deficient, these inorganic deposits are not formed, though this does not much affect the vitality of the organisms, the cell-body of which is then covered only by a delicate, colourless, organic membrane. It still has the same shape as the normal form with its brown envelope, though completely naked cells with a more elongated and very changeable shape are found under unfavourable conditions.

Diversities in appearance similar to those in the few instances mentioned are observed in other iron organisms when investigated in culture, while in Nature the various modifications would not be recognized as belonging to the same organism.

PHYSIOLOGY

Winogradsky's theory of the utilization of chemical energy by iron bacteria [21, 22] is

founded on the observation that certain species—primarily one which we call now *Sphaerotilus discophorus* [17]—flourish in solutions containing ferrous compounds but very little organic matter. The technical difficulty caused by the instability of ferrous compounds in the presence of the oxygen needed by the organisms has so far prevented satisfactory experimental work on autotrophy in iron bacteria. Only in the case of *Gallionella ferruginea* have Lieske [11] and Teichmann [20] had some success when using metallic iron in dilute inorganic nutrient solution enriched with carbon dioxide, but, as Teichmann found, the purer the iron the less successful the cultures. Since commercial iron filings, as used by Lieske, contain carbon and yield hydrocarbons when in contact with water, his experiments are not conclusive.

In order to avoid the experimental difficulties caused by the instability of ferrous compounds, Molisch [14] and Lieske [12] used the more stable manganous salts, assuming that as they are chemically so similar they might be suitable substitutes for the corresponding ferrous compounds. Molisch even adduced this replacement in arguments against Winogradsky, although he employed rather ill-defined preparations such as 'manganese peptone,' and failed when the first supply had run out and he tried further ones. Lieske's cultures with manganous acetate were also not invariably successful. As we know now [16–18], the reason was that an actual replacement of iron by manganese does not take place. Most iron organisms require both these heavy metals; few use iron only, and it is very doubtful if any can altogether dispense with iron. Molisch's and Lieske's failures may have been partly due to the fortuitous lack of the traces of ferrous compounds which are required.

Many misinterpretations in the study of the physiology of iron organisms have been caused by the habitual assumption that iron compounds are wholly responsible for the brown colour of biological deposits. These deposits, it is true, regularly give a ferric reaction, but their colour is due to an admixture of manganic compounds, probably MnO_2 or Mn_2O_3; ferric compounds are not so deeply coloured, and in fact exhibit scarcely any colour in thin layers. When only such layers are present, as in the tubes of *Sphaerotilus natans*, only a faint yellowish tinge can be seen under the microscope.

The reason why manganous salts alone cannot be used for growing iron organisms is probably the fact that, at pH values at which such organisms can live, the oxidation of manganous compounds does not readily take place. When ferrous or organic compounds are present, and these are oxidized by molecular oxygen, probably only one of the two atoms is primarily used, the other being left in an activated state to oxidize manganous ions. The two metals very often go together in nature, but the purity of marsh-ore is partly due to its being a product of *Sphaerotilus natans*; this does not precipitate manganic compounds, and when in small quantities its sheaths do not exhibit any colour and were therefore often stated to contain no iron.

For the rest, iron organisms, apart from oxidizing ferrous and manganous compounds, may have very diverse nutritional habits. *Gallionella* is probably strictly chemo-autotrophic and not able to use organic compounds; *Sphaerotilus natans* is ambitrophic, utilizing either inorganic or organic oxidizable substrata; and *S. discophorus* is mixotrophic, usually consuming both simultaneously. Both species of *Sphaerotilus* grow well, however, without depositing inorganic layers on their sheaths, and there are many other iron organisms in the metabolism of which oxidation of inorganic compounds is not obviously of great importance. Either these are algae with chlorophyll which live photosynthetically—as do for instance *Myxophyceae*, *Euglena*, *Spirogyra*, some *Chlamydomonadaceae*, and others; or they are colourless flagellates, belonging to the *Monadaceae*, *Amphimonadaceae*, or *Bikosoecaceae*, e.g. *Poteriodendron* (figure 7). These flagellates are all phagotrophic, a mode of nutrition characterized by capture of food particles which are digested in vacuoles within the cytoplasm. The significance of the oxidation of ferrous and manganous compounds by these organisms is not known. The output of energy cannot be considerable, because the turnover is much less than in iron bacteria; it would presumably be still less in chlorophyll-containing algae with their other means of acquiring energy.

ECOLOGY

The localities where iron organisms occur are manifold, but all of them are characterized by a close vicinity to places where iron and manganese are in the reduced state and where oxygen is present. By catalysing the oxidation of these metallic compounds, iron organisms become the reactors at which transfer of energy is taking place. This happens, for instance, in water from chalybeate wells; this contains ferrous bicarbonate formed by the action of aqueous carbon dioxide on ferruginous rocks. It seems that a layer of
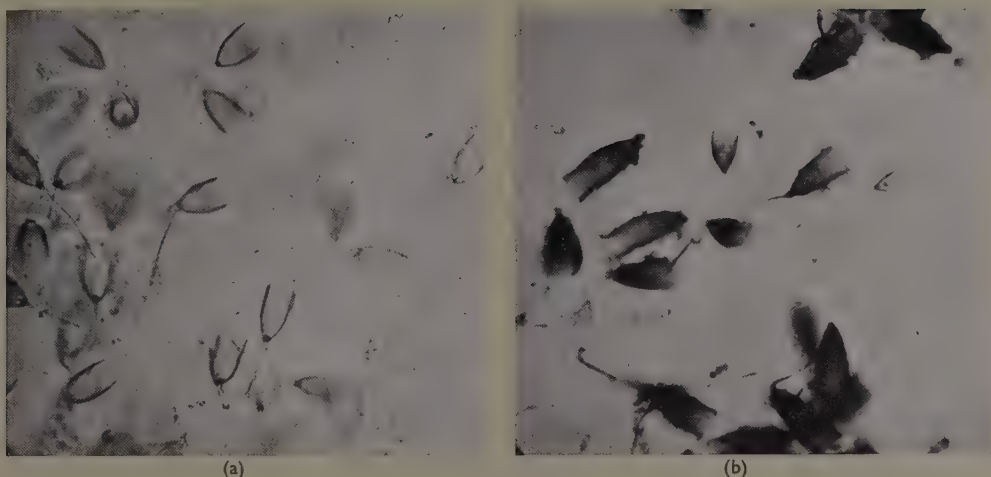
FIGURE 1 – Bikosoeca petiolata. (a) *Goblets of ferric hydroxide.* (b) *The same, Prussian blue reaction; note differences in intensity of staining.* (× 580, *photo. by C. F. Robinow, Strangeways Research Laboratory, Cambridge.*)
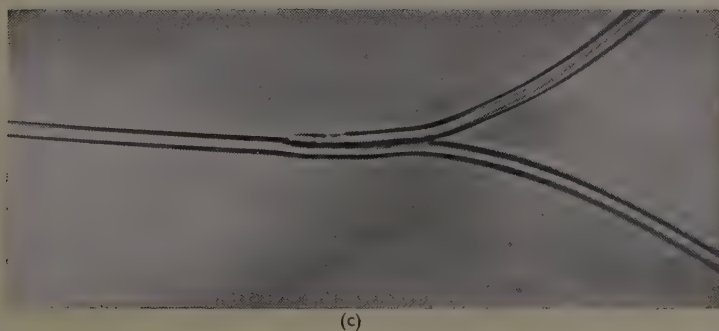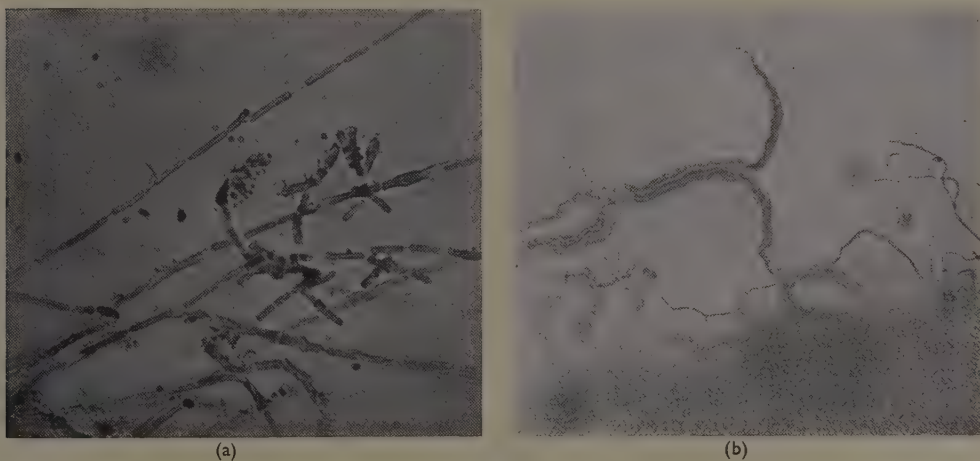
FIGURE 2 – Sphaerotilus natans. (a) *Growth on glass slide immersed in activated sludge; filaments and rods. Delicate sheaths, false branching just starting in filament on left; stained.* (× 840, *photo. by T. G. Tomlinson, Water Pollution Research Laboratories, Minworth, Birmingham.*) (b) *Colony on agar; curly and parallel growth of filaments.* (× 45, *photo. by C. F. Robinow.*) (c) Cladothrix-*form with false branching and thick* Leptothrix *sheaths of ferric hydroxide.* (× 770, *photo. by C. F. Robinow.*)
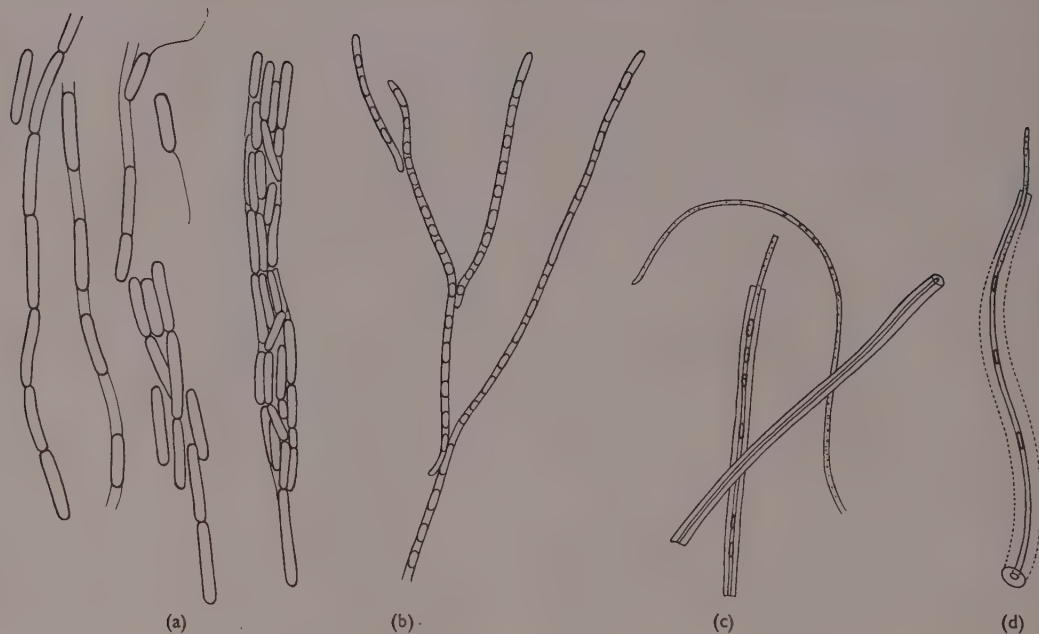
FIGURE 3 – Sphaerotilus natans. (a) *Form from strongly polluted water with delicate sheaths which at places become softened and widened so that arrangements of more than one row of bacterial rods occur;* Pseudomonas-*like swarmers are formed.* (b) Cladothrix-*form from water with little organic matter. Sheaths are delicate and without deposits of ferric compounds but sufficiently tough to keep the bacterial rods together.* (c) Leptothrix-*form with thick colourless sheath recalling glass tubing, and filament without sheath.* (d) Sphaerotilus discophorus; *wide, but tapering, ill-defined brown sheath.*
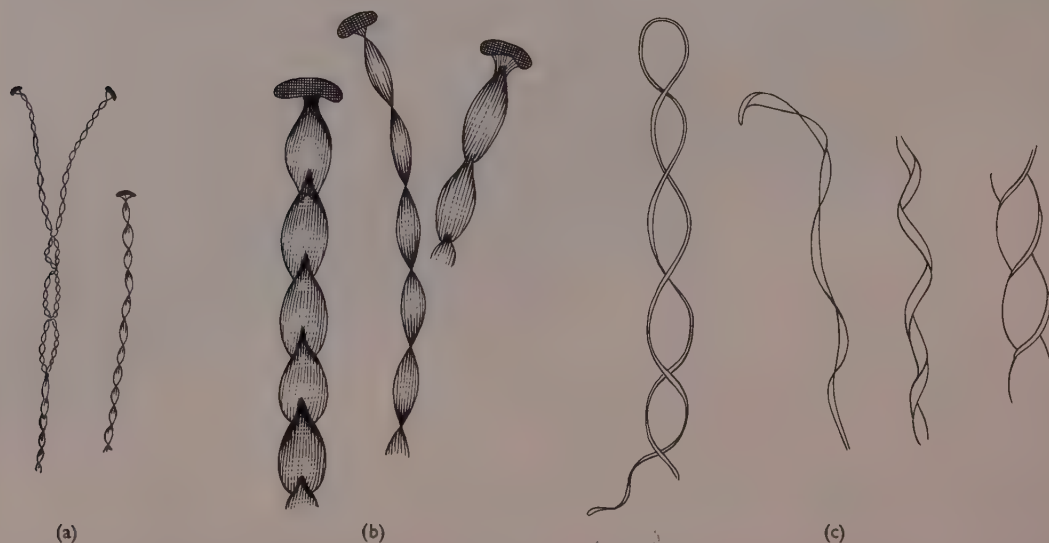
FIGURE 4 – Gallionella ferruginea. (a) *Bacterial cells at the ends of twisted stalks exuded by them, and consisting of ferric hydroxide stained by manganese; on left, appearance after division.* (b) *The same, higher magnification.* (c) *Various figures of stalk formations; on left, two stalks wound round one another.*

FIGURE 5 – Anthophysa vegetans. *The stalked and the free-swimming forms.*
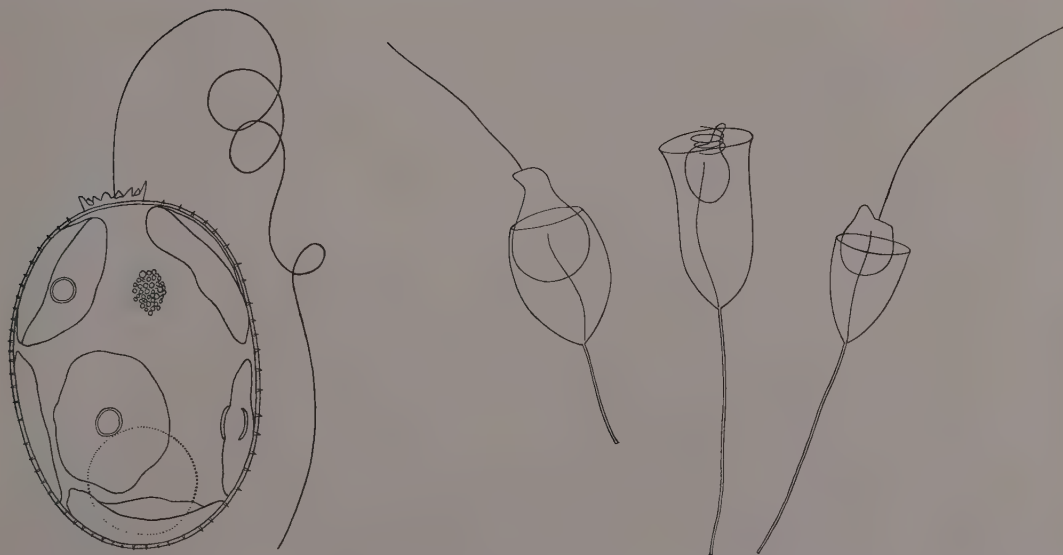
FIGURE 6 – Trachelomonas hispida. Euglena-like cell with an envelope of iron and manganese compounds, ornamented with a crown-like collar and spines. Chromatophores, eye-spot, and flagellum are shown; nucleus near the posterior end.

FIGURE 7 – Bikosoeca lacustris (*left*) *and* Bikosoeca (Poterio-dendron) petiolata, *with fully developed goblet of colourless ferric hydroxide and coiled flagellum* (*middle*); *on right, the same before completion of goblet.*

gaseous carbon dioxide over the water may delay auto-oxidation by preventing atmospheric oxygen from reaching the solution. When such chalybeate waters are bottled for medicinal use, the organisms must be killed by pasteurizing, or a surplus of carbon dioxide must be present in the bottle; otherwise all the iron is precipitated by the iron bacteria and the value of the water lost. *Gallionella ferruginea* and the so-called *Leptothrix ochracea* are found viable and active in such waters.

Other localities where iron organisms live are the margins of bogs from which acid water runs through ferruginous deposits or layers; here it dissolves ferrous compounds and is neutralized. Acidic humus substances from bogs act in two ways: by keeping iron and manganese in solution as complex compounds, and by preventing oxidation. Both these effects can be demonstrated by experimental models on a small scale. In a similar way, iron and manganese are reduced, and complex formation takes place, in polluted streams and pools—for instance, where organic substances are furnished by the excreta of cattle and water-fowl. The development of iron organisms of almost every description may be very pronounced in such places. They are accompanied by other algae and by animals which, without depositing inorganic compounds in a visible way, are similarly adapted to relatively high concentrations of ferrous and manganous compounds—substances toxic to most living things.

The state in which iron and manganese are present in polluted waters is difficult to establish. Most of it is there not as ions but, it seems, as complex compounds with chelating agents of different degrees of stability, and only the free, active ions take part in biological reactions. When consumed they are replaced by others, by disturbance of the unstable equilibrium. Since the toxicity of ferrous and manganous compounds is thus reduced, this kind of accumulator action is beneficial to the organisms, in addition to preventing the oxidation and precipitation of compounds which would thus be unavailable. The organisms appear to acquire their share of these metal compounds by binding them to chelating agents situated in the surface layer of the cytoplasm, but the fixing power of various organisms is different. Iron organisms may, then, be assumed to have less active chelating substances, and therefore to be able to live in places where other organisms are poisoned by ferrous and manganous ions.

Iron bacteria play a part in the rusting of pipes and other iron structures in soil and in water, by first utilizing ferrous bicarbonate, originating from the action of aqueous carbon dioxide on commercial iron, and then producing a crust which separates regions where reducing processes are prevalent from those where oxidation takes place. No iron organisms are known to occur in seawater, which precipitates humus substances and other complex-forming agents, and in which ferrous bicarbonate does not seem to be formed owing to the alkaline reaction and to the presence of too large concentrations of magnesium and calcium salts. The conditions here are not favourable to the retention of iron and manganese in solution, except in extremely low concentrations.

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Ozone in the Earth's atmosphere

G. M. B. DOBSON

Although ozone is present in the atmosphere in only very small quantities, mostly at considerable heights, it nevertheless plays a very important role. Its strong absorption of both ultra-violet and infra-red radiation, for example, has important meteorological consequences which, however, cannot yet be fully appreciated owing to lack of detailed information about its variation from day to day. This deficiency, which also limits our appreciation of the importance of ozone in other respects, is about to be made good by means of regular daily measurements of atmospheric ozone at fifteen different stations in or near western Europe.

Ozone is one of the rarest of the gases which form the Earth's atmosphere. On the average, there is only one molecule of ozone to every four million molecules of the other gases. Further, this very small amount of ozone is found largely at a great height, above 10 km, and the centre of mass of the ozone as a whole is above 20 km. One might therefore wonder why this gas has any meteorological interest. There are four main reasons:

1. It has a very strong absorption band for ultra-violet radiation extending from about 3200A to 2200A, and thus absorbs practically all the solar radiations between these wavelengths before they reach the lower atmosphere. One consequence of this is the existence of a region of relatively high temperature at about 40–50 km. Ozone has a further strong absorption band for infra-red radiation, centred at about 9·7 μ. It thus absorbs an appreciable part of the outgoing radiation from the earth, and may be of importance in the heat-balance of the lower stratosphere.

2. The amount of ozone in the atmosphere at any place outside the tropics is found to undergo quite large day-to-day variation. Variations of 25 per cent. are quite common between one day and the next, and are found to be very closely connected with other meteorological conditions, such as the depressions and anticyclones which dominate the weather.

3. The distribution of ozone over the world is very peculiar, and it is probable that fuller understanding of this peculiarity will allow us to draw conclusions about the general circulation of the atmosphere at high levels.

4. There is a very small amount of ozone in the air near the surface of the ground. This ozone is rapidly decomposed into oxygen by organic material at the surface, and is continually replaced by fresh ozone brought down by turbulence from the upper layers. A study of the variations of the surface ozone will therefore give us information about the turbulence in the lower atmosphere.

FORMATION OF ATMOSPHERIC OZONE

While there is as yet no certain proof, it is highly probable that the main process forming ozone is the action of solar ultra-violet radiation on oxygen in the upper atmosphere. The photochemical reactions forming ozone are:

$$O_2 + h\nu \rightarrow O + O \ \dots\dots\dots (1)$$
$$O_2 + O + M \rightarrow O_3 + M \ \dots\dots (2)$$

where M is a third body taking part in the collision and required for energy conditions, but not altered chemically. Those decomposing it are:

$$O_3 + O_2 \rightarrow 2O_2 + O \ \dots\dots (3)$$
$$O_3 + O \rightarrow 2O_2{}^* \ \dots\dots\dots (4)$$
$$O_3 + O_3 \rightarrow 3O_2{}^* \ \dots\dots\dots (5)$$
$$O_3 + h\nu \rightarrow O_2 + O \ \dots\dots (6).$$
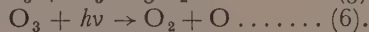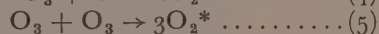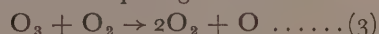
The amount of solar energy absorbed by the ozone in (6) is large, but since the free atom of oxygen will quickly unite with a molecule of oxygen to give ozone again (2), it is probable that little ozone is destroyed in this way.

METHODS OF MEASURING THE AMOUNT OF OZONE IN THE ATMOSPHERE

To determine the total amount of ozone in the atmosphere, the best method is to measure its absorption of solar radiation, and thence to calculate the amount of ozone traversed by the radiation. The wavelengths must be suitably chosen since if there is too great absorption the radiation reaching ground level will be too small to measure accurately, while if the absorption is too small the effects of scattering of the radiation by dust ·

and other disturbing factors will be relatively large, and make the measurements inaccurate. Figure 1 shows strikingly how accurately the measurement can be made in the clear atmosphere of Arosa. The figure gives the amounts of ozone measured through the day using three different wavelengths. On this particular day, there was only a very small real change of ozone, and it will be seen that most of the observations agree within ± 0·5 per cent. It should be emphasized that the values obtained from the three different wavelengths are really entirely independent of each other. The points shown in the upper part of figure 1 are the actual absorptions measured by the instrument for one wavelength, and as the pathlength through the atmosphere varies with the height of the sun, the actual absorptions vary over a range of ten to one. Yet when allowance is made for the changing pathlength traversed by the sunlight, the amount of ozone in one vertical thickness of the atmosphere is constant to about 1 per cent. When observations have to be made at places with more hazy skies the accuracy is not so good, but since there are very large variations from day to day, and even at times during one day, the accuracy is in general good enough.

FIGURE 1 – *Ozone values through the day at Arosa on 1st May, 1950, measured in 0·001 linear cm, i.e. thickness of ozone if reckoned as one layer in absence of the other gases. The circles, crosses, and dots in the lower part of the figure give the amounts of ozone as measured, using three different pairs of wavelengths. Note the small scatter of the values. The circles in the upper part are the actual measurements as given by the instrument for the wavelengths 3054–3253 A. Their large variation is due to the changing pathlength of the light through the atmosphere at different heights of the sun. Note that, while the measurements vary over a range of 10 : 1, the ozone values deduced from them agree to within 1 per cent. (Data by courtesy of Professor Götz.)*

If, instead of requiring to know the total amount of ozone in the atmosphere above any place, we wish to know the concentration of ozone in the air at a particular level, e.g. ground level, then it may be conveniently measured by a chemical method. Perhaps the most accurate is that developed by Ehmert, in which the air is passed through an absorbing vessel containing potassium iodide and sodium thiosulphate solution. The ozone liberates free iodine, which reacts with the thiosulphate, and the measurement consists in determining the residual thiosulphate.

VERTICAL DISTRIBUTION OF OZONE IN THE ATMOSPHERE

The best method of finding the vertical distribution of the ozone in the atmosphere is to obtain solar ultra-violet spectra at different heights, by the use of rockets or balloons. Up to the present time, most of the balloon measurements have not gone above 30 km. Rockets can, of course, reach heights above practically all the ozone, and at these levels solar spectra can be obtained free from any absorption.

While the determinations by the aid of rockets or balloons are thus the best, they are difficult and expensive to make, and one cannot expect more than a small number of such measurements. The vertical distribution can, however, also be obtained from spectroscopic measurements of skylight, using the wavelengths absorbed by ozone as for the determination of the total amount of ozone. Given a fairly clear atmosphere, the necessary measurements can be made with good accuracy, but the calculation of the vertical distribution of the ozone from them presents difficulties, and at present the results are somewhat uncertain. This is unfortunate, since the measurements can be easily made on a large number of days, and it would be of interest to know the differences in the vertical distribution on days with different meteorological conditions and in many parts of the world. However, it may be possible to use the vertical distribution obtained from balloons or rockets to check the results obtained from the ground observations.

While there is no very good agreement between the different results obtained up to the present time, it may be said that the average height of the ozone is between 20 km and 25 km, while the
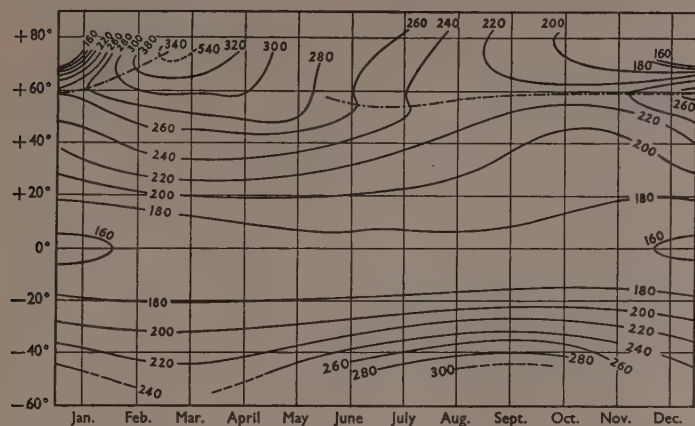
FIGURE 2 – *Graph showing the average amount of ozone for any latitude for the different seasons of the year. (Courtesy of Professor Götz.)*

maximum ratio of ozone to air is found some 5–10 km higher. There appears to be little ozone below 10 km or above 30 km.

GENERAL DISTRIBUTION OF OZONE OVER THE WORLD

As previously mentioned, the distribution of ozone over the world at different seasons is peculiar, and not what might be expected. Figure 2 shows the distribution of ozone with latitude at all times of the year, as given by Götz and based on the whole of the observations available. The outstanding points of interest are:

1. The uniformly low ozone values near the equator at all times of the year.

2. The general increase of ozone values towards high latitudes.

3. The strong annual variation of ozone in middle and high latitudes, with maximum values in the spring in each hemisphere.

4. The indication of maximum ozone values in the winter about latitude 60°, with lower values near the pole, though this characteristic is not yet certain owing to insufficient observations in very high latitudes.

It seems that average ozone values depend only on latitude and not on longitude, though the existing observations are not enough to indicate any possible difference between places having the same latitude, but located on the east and west of the large continental masses.

While the day-to-day values measured at places near the equator show little variation, in middle and high latitudes the variations are very large.

VARIATIONS OF ATMOSPHERIC OZONE WITH WEATHER

In figure 3 the middle curve shows the diurnal variations in the ozone as measured at Oxford from 10th February to 30th May, 1951. (The plotted values are three-day running means.) It will be seen that changes of 0·080 cm in the course of a few days are quite common; this is a change of over 25 per cent. The upper curve shows the thickness of the atmosphere lying between the pressure levels of 300 mb and 500 mb, i.e. it represents the average temperature of the atmosphere between these pressures (approximately between 9 km and 5 km). The lower curve represents the height of the tropopause. The last two curves give the values over Oxford. The plotted values are also three-day running means, as in the case of the ozone. Figure 3 shows the striking connection between the variations in ozone content of the atmosphere and the meteorological conditions in the upper air. The variations of temperature and pressure in the upper atmosphere and the height of the tropopause are all rather closely interrelated, and it is difficult to say with which meteorological characteristic the ozone is most closely connected; probably the relation with the height of the tropopause is as close as any. The correlations between the ozone and the temperature of the upper
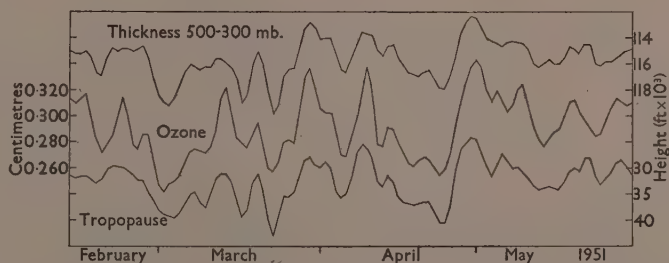
FIGURE 3 – *Middle curve: Daily values of ozone at Oxford, 10th February to 30th May, 1951. Upper curve: Thickness of the layer of atmosphere lying between the pressure levels of 300 mb and 500 mb over Oxford (reversed). This is a measure of the average temperature of the air between these levels. Lower curve: Height of tropopause over Oxford (reversed). (The last two curves are taken from values given on the maps of the Aerological Record of the British Meteorological Office, by courtesy of the Director.)*
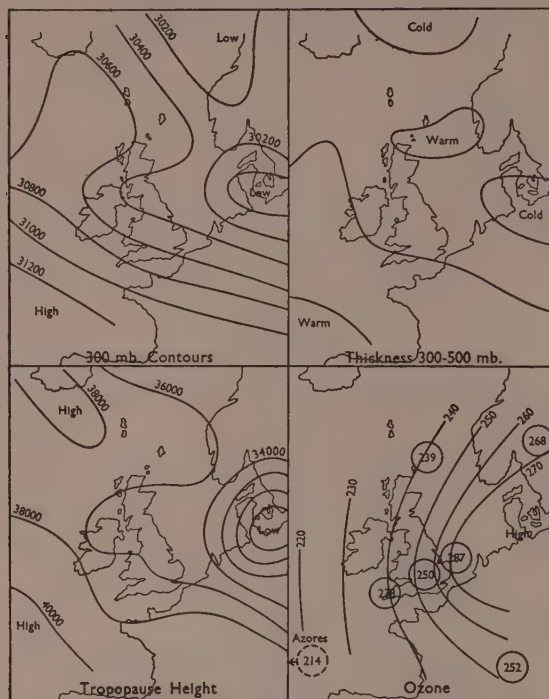
FIGURE 4 – *Upper air conditions of 25th July,* 1951. *Top left : Contours of the* 300 *mb surface in feet. Top right : Thickness of the layer between* 300 *mb and* 500 *mb in feet. Bottom left: Height of the tropopause in feet. Bottom right: Measured values and approximate distribution of ozone. (The first three maps and the ozone values for three points in Britain (Lerwick, Downham Market, and Camborne) are published by courtesy of the Director of the Meteorological Office, the maps being taken from the Aerological Record.)*

troposphere or the height of the tropopause are both negative, and in order to show the relation more clearly the upper and lower curves of figure 3 have been reversed.

A point of some importance is that while the dates of maxima and minima in the three curves of figure 3 show fairly close agreement, the relative magnitude of the changes is by no means constant. Thus, the rise in the three curves between 22nd and 28th March is much the same for all three curves, but the rise in ozone between 5th and 9th April is relatively much greater than that of the two other curves. Again, there is a marked maximum in the ozone on 8th and 9th May, but only a flattening off in the rate of fall of the two other curves.

Since the ozone is mostly situated well above the base of the stratosphere, one might expect that the correlations between the ozone and other meteorological conditions at, say, 20 km would be closer than with those near the base of the strato-

sphere or in the upper troposphere. Observational evidence on this point is somewhat conflicting. Correlations calculated by Meetham, using data obtained by the Dines type of ballonsonde, showed that the correlations between ozone and potential temperature at a given height increased with height up to 18 km, which was the greatest height for which enough temperature data were available. More recent investigations, using data from radio-sondes published in the daily weather report, show decreasing values of the correlation at such great heights.

Figure 4 shows the relation between the variations in the amount of ozone and other meteorological conditions in another way, and the maps give the distribution over north-west Europe of the four characteristics: pressure in the upper atmosphere (300 mb contours), temperature of the upper troposphere (300–500 mb thickness), height of the tropopause, and ozone. The first three maps are taken from the Aerological Record, Meteorological Office, and are for 15·00 h on 25th June, 1951. The ozone values are for the same day about noon. Up to the present time, ozone measurements are available from only seven stations, so that there is much uncertainty in drawing the equal ozone lines; it is, however, clear that the area of high ozone is closely associated with the area of low pressure and low tropopause. Note the relatively low ozone value at the Shetland Isles associated with a ridge of high pressure and high tropopause extending in from the west. The normal variation of ozone with latitude would give a higher ozone value at Shetland than in south England. There is reason to think that the measurement of ozone in Norfolk was somewhat too high. On this occasion, the temperature of the upper troposphere showed rather small variations, but in most cases the connection is similar to that with, say, the height of the 300 mb surface.

It is hoped that, in the near future, measurements of atmospheric ozone will be made daily at eight stations in addition to those shown in figure 4, namely in Spitsbergen, Norway, Iceland, Denmark, Northern Ireland, France, Belgium, and Spain. When all these stations are giving daily values it should be possible to get a fairly accurate idea of the distribution of ozone over western Europe.

Perhaps the main problems presented by the ozone observations at present are the cause of the day-to-day variations in ozone and the explanation of their close association with the other characteristics of the upper air. An obvious suggestion is

that large polar or equatorial currents carry with them the ozone and the other meteorological characters of the atmosphere at their origins. This is almost certainly true in part, but it frequently does not hold. The fact that the day-to-day variations in ozone found in middle latitudes are greatest in spring, when the difference between the amount of ozone at the equator and at the pole is also greatest, is in general agreement with this advection theory. However, examination of individual cases of high or low ozone shows that frequently the air at high levels has not come directly from polar or equatorial regions respectively. There are also occasions, particularly in autumn, when the ozone in middle latitudes is greater than that normal for polar regions, when again the advection theory would not hold.

Another possible cause of the variations in ozone might be vertical currents in the air, at a height where the ozone is formed.

As mentioned earlier, ozone may play an important part in the thermal equilibrium of the upper atmosphere. At the present time this part of the subject has not been fully worked out, and no conclusion can be reached with certainty.

OZONE IN THE LOWER ATMOSPHERE

Finally, mention must be made of the ozone in the surface layers of the atmosphere. The amount of ozone in a cubic metre of surface air is probably never more than a tenth of that present at 20 km, while the proportion of ozone to air is not more than about a hundredth of that at, say, 30 km. It is generally most convenient to measure the ozone in surface air by a chemical method, but spectroscopic methods have been employed, using a mercury lamp as source and measuring the absorption of the 2536A line, which is near the centre of the ozone absorption band.

The amount of ozone in surface air varies greatly, and at times may be practically zero. It is probable that the ozone in surface air has been carried down by turbulence from the ozone-rich region above. Its life is very short in air containing any oxidizable material such as smoke. As would be expected, there is a strong diurnal variation, with low values at night and high values during the day, when there is strong convection.

Book reviews

Soviet Genetics, by A. G. Morton. Pp. 174. Lawrence and Wishart, London. 1951. 15s.

An interesting essay could be written on the function of criticism in science. Literature, music, and art all support professional critics: science has none at all. Nevertheless, criticism does operate quite effectively in the scientific world. Trivial work is simply not noticed; it does not even reach the monographs. Inaccurate work, if it is on important enough subjects, is sooner or later exposed by better work. There is an accepted technique for disproving another scientist's assertions. It is not done by counter-assertions, nor nowadays by clever polemics; it is done by publishing data which are so carefully documented that they convince the reader, but which are obviously inconsistent with the other scientist's assertions. If, for instance, a scientist claims to have synthesized sugar from carbon dioxide in the presence of platinum, the only way to disprove the claim is for a sufficient number of other scientists to repeat the experiment, and to convince the reader that they have failed to get any sugar.

This technique of criticism raises an important question. When is a scientist's assertion so improbable, so fantastic, that his colleagues are not under any obligation to test it, and can reject it outright? Most experienced scientists would reply: never. Yet this is what has happened in the unhappy history of the controversy between so-called western and so-called Soviet genetics. A nation which produced Mendeleev, Lobachevsky, Pavlov, and Vavilov cannot be dismissed as unscientific. This nation has also produced Lysenko; he is at present an Academician and the director of an important institute. He asserts that he has changed the heredity of certain plants by experimental treatment. How should other biologists treat this assertion? The conventional way would be (a) to translate his papers, (b) to examine his accounts of the techniques he uses and the data from which he draws his conclusions, and (c) to repeat his experiments and to publish the results. One has only to glance at the comments of British and American biologists on Lysenko's work to see that for Soviet genetics the normal apparatus of criticism has broken down. When, in 1949, an American professor wrote a book about the Russian genetics controversy, he appended a four-page bibliography which includes the names of many very distinguished British and American geneticists; but not one of them had repeated any of Lysenko's experiments before commenting on his assertions.

Why is this? One can attribute it partly to Lysenko's own florid and hysterical style of writing; but only partly, because most of Lysenko's critics have never read his original papers in any case. One can attribute it partly to the fact that Lysenko incidentally refutes the work of most other geneticists, but this of course does not prove that his own experimental data are worthless. One can attribute it partly to the fact that the original data are in Russian, and Russian is an unfamiliar language spoken by a people whose politics are distasteful to us. Even if we make allowance for all these

reasons, we cannot help feeling that the rejection of Lysenko's claims (though history will surely confirm that they should be rejected) has not been made according to the dignity and traditions of European science. There is only one full account in English of a repetition of one of Lysenko's key experiments: the paper by Wilson and Wittmer in the *American Journal of Botany*, vol. 33, 1946; and even this paper has been overlooked by most of Lysenko's critics. Even the very careful account, in German, by E. Sankewitsch (*Arbeitsmethoden der Mitschurinschen Pflanzenzüchtung*, 1950) does not include enough data to enable the reader to make up his own mind.

What we need, therefore, is not pamphleteering by indignant western biologists (who would never use this means to criticize one another's work), but a literal translation of the key papers upon which Soviet geneticists base their assertions, together with comments on the practical techniques they use. At first sight Dr Morton's book promises something like this; he has access to some, at least, of the original papers. He says in the preface that he has read and translated them himself. He has a biological training. He seems at first sight to be writing for fellow biologists. One hopes therefore to find the traditional western approach: an impartial summary of Lysenko's data and sufficient comment to enable the reader to decide for himself whether the data merit serious consideration. There is, for instance, an important paper by A. A. Avakyan and M. G. Yastreb in the journal *Yarovisatsia* on graft hybridization in tomatoes, with coloured plates and ten tables. Any geneticist who reads this paper can draw his own conclusions as to the *bona fides* of Soviet genetics. Dr Morton presumably had access to this paper, for he quotes from another paper, by Berezniakovskaya, which is in the same volume. If he had translated it, and others like it, he would have done a useful service to genetics on both sides of the iron curtain, for it would have dispelled the misrepresentation of Lysenko's case; and, as Dr Morton himself quotes on his title page, 'Great is the power of steady misrepresentation; but the history of science shows that fortunately this power does not long endure.'

But Dr Morton has done no such useful service. His book will not dispel any of the misrepresentation. Instead he merely tells us, with scarcely any quantitative data, about his impressions of the writings of Soviet geneticists. His attitude to the assertions made by Lysenko and his school is deeply influenced by his own philosophical opinions, which resemble those of a Marxist. He supports the dialectic view that 'the decisive test of the correctness of a theory . . . lies in the extent to which the theory can be used to give practical control of nature by transforming it.' Considered as a summary of Michurinian genetics written for Michurinians, the book is concise and competent. Considered as an objective account of Michurinian genetics written for the scientist who wishes to know what the evidence is, the book cannot be recommended. It contains several mistakes (e.g. the statement on page 15 that 25 million acres of vernalized grain were sown in 1941, and the discussion of hybrid vigour on pp. 88–9); its factual summaries suffer because they are all *oratio obliqua*; and they are reported by a writer who gives the impression that he has set out to justify his loyalty to Michurinian genetics rather than to the scientific method.   E. ASHBY

BRITISH AGRICULTURAL BULLETIN

British Agricultural Bulletin, May 1952. *Pp. 64, with numerous half-tone illustrations. The British Council, London. 4s. per issue. Annual subscription one guinea.*

This bulletin is a well-balanced and well-illustrated bi-monthly publication of the agricultural department of the British Council, now in its fifth year. In the beginning, the purpose of the bulletin was to tell the story of British farming and agricultural research to countries in the Commonwealth and Empire, and to such foreign countries as could be reached. More recently the aim has been expanded, to put similar knowledge from the whole Commonwealth at the disposal of farmers and interested citizens of other countries.

The way in which this aim is being achieved is evident in the May 1952 number of the bulletin, which contains authoritative articles on agricultural progress in Northern Ireland (a historical review), the place of agriculture in the Canadian economy, and an account of work being carried out at the agricultural research institute at Pretoria, South Africa. Foreign interest in Britain's pedigree livestock industry is met by accounts, with excellent illustrations, of the 1952 Scottish dairy show and other prominent livestock events, such as the Perth shows and sales for animals of the Scottish Shorthorn and Aberdeen Angus breeds and the Hereford bull sales.

Notable scientific articles and reports published elsewhere are reproduced, and there is a comprehensive book review section.   J. EDWARDS

A NEW SCIENCE

Radio Astronomy, *by Bernard Lovell and J. A. Clegg. Pp. 238, with 120 figures. Chapman and Hall Limited, London. 1952. 16s. net.*

There is special appropriateness in one of the volumes in the 'Frontiers of Science' series being devoted to the subject of radio astronomy, for though the discovery that radio waves are reaching the Earth from some source in space was made by Jansky as long ago as 1931, radio astronomy is essentially a new branch of science, whose development has taken place almost entirely within the last seven years. The subject has grown with unprecedented rapidity, facilitated by the extensive application of radar methods in the last war, and already has an extensive literature. The equipment and methods used are those of the radar engineer, and are very different from those used in the older branches of astronomy. So much has already been achieved that the time had arrived when a survey of the subject could usefully be made. It is fitting that the senior author of this book should be the occupant of the first university chair of radio astronomy to be created.

In order that the book may be as useful as possible to a wide range of readers, the authors start with statements of the fundamental ideas of astronomy on the one hand, and of radio methods of investigation on the other. The applications of radar methods to the study of meteors, and the results obtained, are then dealt with. The observations of solar and galactic radio emissions and their possible interpretation are considered. The puzzling phenomenon of the radio stars is described. The use of radar methods for the investigation of the Moon and of the *aurora polaris*, and their possible extension to the planets and the *Gegenschein*, are also included. The volume provides an excellent introduction to the subject.

The construction has been approved,

and is shortly to be put in hand, of a great radio telescope under the direction of Professor Lovell: it is a steerable paraboloid of 250 feet aperture. With this equipment it will be possible for many of the subjects of investigation discussed in this book to be greatly extended. It is inevitable that it will not be long before a revised, and no doubt enlarged, edition will be called for.   H. SPENCER JONES

STUDIES OF SCORPIONS

Études sur les Scorpions, *by Max Vachon, with a preface by L. Fage. Pp. 482, with 697 figures. Institut Pasteur d'Algérie, Algiers. 1952. 2200 fr. net.*

This is a valuable work, but it should at once be stated that a more descriptive title would have been 'A Revision of the Scorpions of North-West Africa,' although the first two chapters are of general application.

Chapter I deals with the external and internal morphology and the habits of scorpions (to which surprisingly little attention has previously been paid). Chapter II examines the relative values of different morphological characters in the classification and identification of scorpions. Conclusions likely to influence the future description and determination of species are reached. In particular the importance of trichobothria (sensory hairs) on the pedipalps is rightly emphasized.

The remainder of the work (422 out of 482 pages) sorts out and gives descriptions and the distribution of all known scorpions inhabiting Morocco, Algeria, Tunis, and the Sahara. The author recognizes 33 species (58 forms) arranged in 15 genera. He describes 4 new genera, 9 new species, and 7 new sub-species and varieties. He discusses the origin of the fauna of this area, besides illustrating with maps the present distribution.

Descriptions and illustrations are excellent. Indeed, this work tempts us to wish that its gifted author could undertake a comprehensive comparative study of the scorpions of the world, which number, so far as is at present known, only about 600 species. Literature is scattered, descriptions are often inadequate, and the synonymy is confusing, but such a task would not be beyond the scope of one man freed from other duties.   W. S. BRISTOWE

[*Editorial note.* We hope shortly to publish an article by Dr Vachon describing some of his researches upon scorpions.]

OCEAN WAVES AND TIDES

Waves and Tides, *by R. C. H. Russell and D. H. MacMillan. Pp. 348, with 16 plates and numerous line diagrams. Hutchinson's Scientific and Technical Publications, London. 1952. 25s. net.*

This volume is in effect two books in one, Mr Russell's section on waves being quite independent of Commander MacMillan's section on tides; both are addressed to those who want a general but precise statement of what is now known on these rather elusive subjects. That is to say, the authors have struck a mean between the comprehensive advanced textbook and the popular science book which should prove of considerable value.

In the section on waves, the theories of Airy, Stokes, Rankine, Kelvin, and others are lucidly reviewed, and are compared with the findings of such observers as Cornish and recent investigations by the Admiralty research laboratory. Reflection, diffraction and refraction effects, wave currents, and the generation of waves by wind are considered at some length, and there are valuable chapters on wave pressures and the movement of material by waves in relation to coast erosion and storm damage to structures.

In the second portion of the book, the tides are examined in a manner which is less detailed but more readable than the standard Admiralty 'Manual of Tides.' The accepted theory of equilibrium tides, modern tidal theory, and tide prediction receive a clear, largely non-mathematical treatment, and chapters have been devoted to tidal streams, and to the effects of weather on tides and of tides on navigation. The author has also found room for an interesting historical review of his subject.   FERGUS ALLEN

COMPASSES

From Lodestone to Gyro-compass, *by H. L. Hitchins and W. E. May. Pp. 219, with numerous half-tone and line illustrations. Hutchinson's Scientific and Technical Publications, London. 1951. 12s. 6d. net.*

The great importance of compasses, both magnetic and gyro, in navigation has resulted in many highly technical books discussing the details of their construction, installation, and maintenance under various conditions. The present work is of quite a different kind; it is not intended for the user of compasses but for those with a general curiosity about the history and present forms of

these interesting instruments. This aim the two authors admirably fulfil, within a small volume and keeping technical discussion to the barest minimum. In the final chapter is a discussion of sun-compasses, various types of which proved of outstanding importance during the last war in desert fighting in north Africa.

The increasing demand for exceedingly precise navigation both at sea and in the air makes the provision of accurate magnetic charts of the greatest importance. It is, therefore, both disappointing and surprising to learn that a decision has been taken by the Admiralty not to continue with the construction of the wooden non-magnetic ship *Research*, which could have continued the valuable surveys made by the American non-magnetic yacht *Carnegie* before her accidental loss by fire in 1929.

SOCIAL TECHNOLOGY

The Chemical Revolution, *by Archibald and Nan Clow. Pp. xiv + 680, with numerous half-tone illustrations. Batchworth Press Limited, London. 1952. 50s. net.*

This book, which is described as a contribution to social technology, is unique, and the amount of research involved in writing it must have been very great. In manuscript, the work was awarded the senior Hume Brown prize by the University of Edinburgh. The aim of the authors has been to emphasize the social and economic consequences of advancing scientific development during the so-called Industrial Revolution—which was not so much a revolution as a slow evolutionary change—and to see clearly why and how innovations took place, as well as to link them with the social needs that prompted the solution of particular technical problems. It is pointed out in the introduction that the time of departure is approximately the year 1750, and that the enormous mass of material to be handled forced a stop at about 1830. The method adopted in the presentation has a distinct Scottish bias, but the work does not suffer on that account.

It is not possible to go into detail concerning the various chapters, but one is led logically from minerals and manufactures through industries well known, such as paper, glass, pottery, and iron, and others not so well known —for example, kelp, mordants, tar, and matches—to farm factories and

the economy of vegetation, and always with a balanced presentation and a fine choice of quotation. In addition, there are 16 diagrams illustrating the evolution and ramifications of various industries; these are supported by a coloured frontispiece and 110 illustrations. There are also a 9-page chemical chronology and a 28-page bibliography, while the index, printing, and paper are excellent.

At first sight, the use of the Mumford and Geddes terminology may seem strange, and the discussion of eotechnic, palaeotechnic, and neotechnic phases of development a little heavy, but one soon sees that this procedure is very helpful. The book will be useful not only to those interested in the history of industrial development but particularly to those concerned with social technology and its implications.

ARTHUR MARSDEN

RADIOACTIVITY IN CHEMISTRY

Radioactivity Applied in Chemistry, edited by A. C. Wahl and N. A. Bonner. Pp. 604. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1951. 60s. net.

The field of radioactivity in its chemical aspects is expanding so rapidly that keeping a bibliography on a limited part of it is as much as any individual can be expected to do. Coming at the present time, a book such as this one is most welcome. It is the joint production of twelve authors, who have conducted an intensive search of the literature relating to the applications of radioactivity to chemistry, from the earliest work until 1949–50. More than fifteen hundred references have been consulted, and information from them has been presented to the reader in such a manner that he can quickly find out what has been done in a particular branch of chemistry.

Half the book consists of chapters showing the way in which radioactive methods are applied to a given type of study. The remainder of the text consists of tabulated information under subject headings, and here the findings of many experimenters are made available in a surprisingly concise form.

The chemist who wants an easy introduction to the subject should look for it elsewhere. The book will appeal most to the student and the specialist. It will be a most useful reference book for many years to come. W. J. ARROL

ADVANCES IN PHYSICS

Advances in Physics, edited by N. F. Mott. Vol. 1, No. 1. Pp. 109. Taylor and Francis, London. 1952. 15s. net. (Four issues 55s. net.)

'Advances in Physics' is published as a supplement to 'The Philosophical Magazine' and is edited by N. F. Mott. The editorial policy is to publish review articles by experts for experts, covering all topics of current interest in physics and in some branches of applied mathematics. Quarterly publication should allow reviews to appear much more quickly than, for example, in the Physical Society's 'Annual Reports on Progress in Physics.' Each issue will contain a group of articles on more or less related topics, so as to appeal to the research worker who is not a regular subscriber. The first contains three articles: on electrons in metals by E. H. Sondheimer, on the generation of vacancies in moving dislocations by F. Seitz, and on crystal growth and dislocations by F. C. Frank. These articles set a high standard, and are long enough to survey the field adequately. Further issues are planned on liquid helium, the theory of dislocations, and the upper atmosphere. Each number will certainly be welcomed by specialists in the field concerned, but the physicist who wishes to keep up to date with branches of physics other than his own will probably continue to look to the 'Annual Reports' for the purpose.

J. M. M. PINKERTON

LABORATORY INSTRUMENTS

Laboratory Instruments—Their Design and Application, by A. Elliot and J. Home Dickson. Pp. 414. Chapman and Hall Limited, London. 1951. 32s. net.

This book contains a wealth of information of practical value to the research worker who has to design his own equipment, and should be generally useful to all engaged on instrument construction. It is based on the wide experience of the authors accumulated during many years of research, and the application of the principles laid down should enable even the beginner in research to design instruments which will work successfully with the minimum of unnecessary elaboration. No attempt has been made to cover the whole instrument field, and the main emphasis is on mechanical construction and on optical instruments.

The first few chapters deal with the

properties and treatment of various materials, the preparation of drawings for workshop use, and the capabilities of workshop machines. There is a detailed discussion of the kinematic design of instruments, containing many excellent examples of simple and effective pieces of equipment constructed on these principles. Chapters on vibration-insulation, sensitivity, and methods of measurement follow. The importance of optical instruments and photography in nearly all research calls for special attention, and much information of a type not normally included in books on optics occupies the remaining space. There are many valuable tables and diagrams illustrating the uses of lenses, mirrors, and prisms, and finally a series of appendices containing miscellaneous information relevant to the various topics discussed.

W. C. PRICE

SILK

Silk: Biology, Chemistry, Technology, by Paolo Carboni. Pp. xi + 248, with many line diagrams and half-tone illustrations. Chapman and Hall Limited, London. 1952. 37s. 6d. net.

This book by Dr Carboni deals with the biology, chemistry, and technology of silk, with emphasis on the physical and chemical characteristics of the cocoon and the raw silk of commerce. The reeling and testing of raw silk are described fully and authoritatively but, understandably, with special reference to Italian practice. There are useful chapters on the throwing of silk and the production of spun-silk yarns from silk wastes. The description of silk-dyeing processes is mainly restricted to details of the tin- and vegetable-weighting of silk. The final chapter of the book concerns analytical methods.

It is to be regretted that there is much room for criticism. The book lacks scholarship, and there are many errors which could have been eliminated by a second reading. The translator is obviously not familiar with scientific expression in general and the terminology and nomenclature of silk technology in particular. The line drawings are well reproduced, but some of the half-tone illustrations are useless. No attempt has been made to describe the recent advances in our knowledge of silk fibroin and sericin. Attention to these and other points would have resulted in a valuable contribution to the literature. F. O. HOWITT

Some books received

BIOLOGY

Cybernetics: *Transactions of the Eighth Conference*, 15–16th March, 1951, edited by Heinz von Foerster. *Pp.* 240. *Josiah Macy Jr. Foundation, New York*. 1952. $4 *net*.

Genes and Mutations: *Cold Spring Harbor Symposia on Quantitative Biology. Vol. XVI. Pp.* 521, *with many half-tone and line illustrations. The Biological Laboratory, Cold Spring Harbor, Long Island, New York*. 1951. $9 *net*.

Metabolism and Function in Nervous Tissue, *edited by R. T. Williams. Biochemical Society Symposia No. 8. Cambridge University Press, London*. 1952. 12s. 6d. *net*.

Problems of Life, *by L. von Bertalanffy. Pp.* 216. *Watts and Company, London*. 1952. 25s. *net*.

CHEMISTRY

Acids and Bases, their Quantitative Behaviour, *by R. P. Bell. Pp.* 90, *with several line diagrams. Methuen and Company Limited, London*. 1952. 6s. 6d. *net*.

Heterocyclic Compounds (*Volumes III and IV*), *edited by Robert C. Elderfield. Pp.* 441 *and* 674 *respectively. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London*. 1952. 96s. *and* 136s. *net respectively*.

Mixtures, *by E. A. Guggenheim. Pp.* 270. *Oxford University Press, London*. 1952. 42s. *net*.

The Phosphatides, *by Harold Wittcoff. Pp.* 564. *Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London*. 1951. 80s. *net*.

Problems in Physical Chemistry, *by L. G. Sillén, P. W. Lange, and C. O. Gabrielson. Pp.* 370. *Prentice-Hall Inc., New York*. 1952. $6.65 *net*.

Traité de Manipulation et d'Analyse des Gaz, *by Henri Guérin. Pp.* 636, *with several line diagrams. Masson et Cie., Paris*. 1952. *Paper covers* 4500 fr.; *bound* 5100 fr.

Treatise on Physical Chemistry (*Volume II*). *States of Matter, by Hugh S. Taylor and Samuel Glasstone. Pp.* 701, *with several line diagrams. D. Van Nostrand Company Inc., New York; Macmillan and Company Limited, London*. £3 15s. *net*.

GENERAL SCIENCE

The Artificial Satellite, *edited by L. J. Carter. Proceedings of the Second Inter-*national Congress on Aeronautics. *Pp.* 73. *The British Interplanetary Society, London*. 1952. 5s. 6d. *post free*.

Colour in Theory and Practice, *edited by H. D. Murray. Pp.* 360, *with numerous colour, half-tone, and line illustrations. Chapman and Hall Limited, London*. 1952. 70s. *net*.

Cosmology, *by H. Bondi. Pp.* 179. *Cambridge University Press, London*. 1952. 22s. 6d. *net*.

GEOLOGY

Welcher Stein ist das ? *by Rudolf Börner. Pp.* 165, *with several coloured plates. Kosmos-Gesellschaft der Naturfreunde. Franckh'sche Verlagshandlung, Stuttgart*. 1952. DM5.80 *net*.

HISTORY OF SCIENCE

The Alchemists, *by F. Sherwood Taylor. Pp.* 246, *with several line illustrations. William Heinemann Limited, London*. 1952. 12s. 6d. *net*.

British Scientists of the Twentieth Century, *by J. G. Crowther. Pp.* 320, *with several half-tone illustrations. Routledge and Kegan Paul Limited, London*. 1952. 25s. *net*.

Johannes Kepler: Life and Letters, *by Carola Baumgardt. Pp.* 209. *Victor Gollancz Limited, London*. 1952. 12s. 6d. *net*.

The Scientific Work of René Descartes (1596–1650), *by J. F. Scott. Pp.* 211, *with several line diagrams. Taylor and Francis Limited, London*. 1952. 20s. *net*.

The Story of 100 Years of Phosphorus Making: 1851–1951, *by Richard E. Threlfall. Pp.* 400, *with several colour, half-tone, and line illustrations. Albright and Wilson Limited, Oldbury*. 1951. 25s. *net*.

The Story of the Mushets, *by Fred M. Osborn. Pp.* 195, *with many half-tone illustrations. Thomas Nelson and Sons Limited, London*. 1952. 21s. *net*.

INDUSTRY

British Plastics Year Book 1952. *Pp.* 515. *Iliffe and Sons Limited, London*. 1952. 30s. *net*.

The Development of some Man-Made Fibres. *Papers presented at the Annual Conference of the Textile Institute*, 1951, *by A. R. Urquhart, H. J. Hegan, and G. Loasby. Pp.* 79. *The Textile Institute, Manchester*. 1952. 12s. 6d. *net*.

Plastics Molding, *by John Delmonte. Pp.* 493, *with several half-tone and line illustrations. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London*. 1952. 72s. *net*.

Vinyl and Related Polymers, *by Calvin E. Schildknecht. Pp.* 723, *with numerous half-tone and line illustrations. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London*. 1952. 100s. *net*.

METALLURGY

Tungsten (*third edition*), *by Colin J. Smithells. Pp.* 326, *with many line and half-tone illustrations. Chapman and Hall Limited, London*. 1952. 75s. *net*.

PHYSICS

Annual Review of Nuclear Science, *Vol. I*, 1952. *Pp.* 645, *with several line diagrams. Annual Reviews Inc., Stamford, California*. 1952. $6 *net*.

Control and Removal of Radioactive Contamination in Laboratories. *Handbook No. 48. Pp.* 24. *National Bureau of Standards, Washington*. 1951. 15 *cents*.

Cloud Chamber Photographs of the Cosmic Radiation, *by G. D. Rochester and J. G. Wilson. Pp.* 128, *with many half-tone illustrations. Pergamon Press Limited, London*. 1952. 70s. *net*.

Electronic and Ionic Impact Phenomena, *by H. S. W. Massey and E. H. S. Burhop. Pp.* 669, *with numerous line diagrams. Oxford University Press, London*. 1952. 70s. *net*.

Elements of Wave Mechanics, *by N. F. Mott. Pp.* 156. *Cambridge University Press, London*. 1952. 21s. *net*.

Ferromagnetic Properties of Metals and Alloys, *by K. Hoselitz. Pp.* 317, *with several line diagrams. Oxford University Press, London*. 1952. 40s. *net*.

Low Temperature Physics—Four Lectures, *by F. E. Simon, N. Kurti, J. F. Allen, and K. Mendelssohn. Pp.* 132, *with half-tone and line diagrams. Pergamon Press Limited, London*. 1952. 21s. *net*.

The Physical Principles of Thermodynamics, *by R. A. Smith. Pp.* 280. *Chapman and Hall Limited, London*. 1952. 30s. *net*.

The Theory of Relativity, *by C. Møller. Pp.* 386. *Oxford University Press, London*. 1952. 35s. *net*.

Valence, *by C. A. Coulson. Pp.* 338, *with several line illustrations. Oxford University Press, London*. 1952. 25s. *net*.

Notes on contributors

T. P. HILDITCH,
C.B.E., D.Sc., F.R.S., F.R.I.C.,

Was born in 1886 and was educated at Owen's School, Islington, University College, London, and the Universities of Jena and Geneva. Was engaged in industrial research (1911–25) with Messrs J. Crosfield and Sons Limited, Warrington, at first on the development of fat hydrogenation and other catalytic processes, and later on the composition and constitution of fats used in industry. From 1926 to 1951 he held the Campbell Brown chair of industrial chemistry in the University of Liverpool, where he created a school of research on fats which made important contributions to knowledge of the structure of natural fats, of the relation of fat composition to the biological origin of the fat-producing organism, and of the autoxidation of unsaturated fats. Was associated with the Colonial Products Research Council in the investigation of fatty oils from a wide range of botanical species indigenous to various parts of the British Commonwealth. Is now professor emeritus in the University of Liverpool.

A. C. CROMBIE,
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Was born at Brisbane, Australia, in 1915, and was educated at Geelong Grammar School and the Universities of Melbourne and Cambridge. He has published a number of biological papers, mainly dealing with problems of population dynamics and of the chemical sense organs of insects. In 1946 he was appointed a lecturer in the department of history and philosophy of science at University College, London. Since then he has published several historical papers and written two books, which are due to appear shortly: 'Augustine to Galileo. The History of Science, A.D. 400–1650' (Falcon Press, London), and 'Robert Grosseteste and the Origins of Experimental Science' (Clarendon Press, Oxford). He is editor of 'The British Journal for the Philosophy of Science.'

A. BUTENANDT,
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Was born at Bremerhaven in 1903 and was educated at the Universities of Marburg and Göttingen. Has held successively appointments as *privat-docent*, Göttingen (1931); professor of organic chemistry at the Technical College, Danzig (1933); director of the Kaiser-Wilhelm Institute for Biochemistry (1936); and professor of physiological chemistry and director of the physiological chemical institute, Tübingen (1945). Was awarded the Nobel Prize for chemistry in 1939.

THOMAS W. M. CAMERON,
M.A., Ph.D., D.Sc., M.R.C.V.S., C.M.Z.S., F.R.S.C.,

Was born in 1894 and was educated at the Universities of Glasgow, Edinburgh, and London, and the Royal (Dick) Veterinary College. During the first world war he served in the Highland Light Infantry and the Royal Flying Corps. Was a lecturer and Milner research fellow, London School of Hygiene and Tropical Medicine, later serving as senior lecturer in zoology, Edinburgh. Since 1932 has been professor of parasitology, McGill University, and director of the institute of parasitology, Macdonald College. Was elected to the Royal Society of Canada in 1939, and served as president of Section V in 1949–50. Served as president of the American Society of Parasitologists in 1949. In addition to numerous scientific papers has published several books, including 'Diseases of Animals in relation to Man,' 'Parasites of Domestic Animals,' and 'Parasites of Man in Temperate Climates.' Is editor of the 'Canadian Journal of Comparative Medicine.'

W. JACOBSON,
M.D., Ph.D.,

Was born in 1906, and took degrees at Heidelberg and Cambridge. His first papers dealt with questions of cell development and differentiation in early embryonic tissues. The connection between blood-cell formation and pterins was observed by him fifteen years ago. Has investigated this group of compounds and their mode of action, especially in relation to normal and pathological blood cells. Holds a Sir Halley Stewart research fellowship at the Strangeways Research Laboratory, and teaches in the department of physiology, University of Cambridge. Recently spent two years in the United States with the support of the Rockefeller Foundation and the Fulbright Committee, and did research at the Children's Hospital, Boston, on problems connected with the treatment of leukaemia.

M. WEBB,
B.Sc., Ph.D.,

Was born at Alrewas, Staffordshire, and was educated at King Edward's School, Lichfield, and the University of Birmingham. After a short period as an Imperial Chemical Industries research fellow, he was appointed to a lectureship in organic and biological chemistry at Birmingham University. Began research on steroid chemistry but later turned to microbiology, and has published numerous papers on various aspects of bacterial chemistry. Moved to Cambridge in 1949, as a member of the external staff of the Medical Research Council, to develop a biochemical unit at the Strangeways Research Laboratory.

E. G. PRINGSHEIM,
D.Phil.,

Was born in 1881. Was appointed assistant professor at Berlin University in 1920, and professor and head of the department of plant physiology in the German University in Prague from 1923 to 1938. In 1939 he came to Britain as a refugee, with a collection of pure cultures of algae which was reorganized at Queen Mary College, University of London, with the help of Professor F. E. Fritsch. He was then appointed curator of the culture collection of algae and protozoa at the Botany School, Cambridge, for which the university took responsibility in 1947. He retired at the end of 1951, and is now working at the Strangeways Research Laboratory, Cambridge. Has published papers on plant physiology and on the taxonomy and biology of flagellates and algae, and books on the irritability of plants and on demonstration experiments. Has also written a treatise on the preparation of pure cultures of algae (Cambridge University Press, 1946). Gauss-Weber medallist (1950), University of Göttingen.

G. M. B. DOBSON,
C.B.E., D.Sc., F.R.S.

Educated at Sedbergh School and Gonville and Caius College, Cambridge. Research student at Kew Observatory, then first instructor in meteorology at the Central Flying School, Upavon (Royal Flying Corps), 1913–16, and later moved to R.A.E. Farnborough, 1916–19. Reader in meteorology at the University of Oxford since 1919. Research mainly devoted to various problems concerning the physics of the atmosphere.

ENDEAVOUR

The British quarterly scientific review ENDEAVOUR was first published in January 1942. Its purpose was to enable men of science, and particularly British men of science, to speak to the world in an hour when not only nations but the internationalism of science suffered the dangers of warfare. For the better fulfilment of this purpose ENDEAVOUR was from the first published in four separate editions—English, French, Spanish, and German. An Italian edition has been published since January 1948. Today the situation is happily different, but there can be no lasting peace without full and sincere co-operation between nations in every realm of human enterprise. In the scientific field ENDEAVOUR can thus play as useful a part in peace as it did in war, and for this reason the decision has been taken to make its publication permanent.

ENDEAVOUR is distributed without charge to senior scientists, scientific institutions, and libraries throughout the world, the guiding principle being that of helping scientists overseas to maintain those contacts which their British colleagues have always so much valued. Within these limits the Editors are at all times glad to consider the addition of new names to the mailing list.